REGION 2 - U.S. FOREST SERVICE

INTERMEDIATE FIRE BEHAVIOR EXERCISE

FORT COLLINS, COLORADO

MARCH 16-18, 1971

INTERMEDIATE FIRE BEHAVIOR

PROBLEM I

March 18, 1971 1330-1415

Fort Collins, Colorado Quinn, Tice and Todd

Synopsis:

At 1205 on August 4th, Cicero Peak Lookout reports a fire on the west slope of Bowman Ridge. The fire is small and putting up white smoke.

Your six man crew is dispatched from Custer at 1210 and arrive on the fire at 1250 (show slides).

Weather:

Readings at District's Fire Weather Station, 1400, August 3; Temperature 90o, RH 12%, Wind SW 15, SI 68, B.I. 171.

Forecast received 1600 August 3: For tomorrow, (August 4), Mostly clear and slightly cooler with chance of a few isolated thunderstorms. Maximum temperature 80° - 85°, Minimum R.H. 15 - 20%, Wind west 6 - 12 MPH with gusts to 30 in the afternoon. Probability for precipitation 20%, lightning 40%.

PROBLEM I, EXERCISE #1

Fire is burning upslope in grass, litter and scattered brush and is approximately three acres in size.

Describe the behavior you would expect on this fire.

What safety precautions should be taken?

PROBLEM I, EXERCISE #2

1310 August 4 Spot Weather Forecast - Bowman Ridge Fire.

Temperature 95 degrees, RH 15%, Wind East 2-4. Thunderhead buildup passing your fire 1500-1700. Wind shifting west 20-30 with thunderhead passage.

2. What is the anticipated Fire Behavior under predicted conditions? What safety precautions should be taken?

PROBLEM I, EXERCISE #3

The thunderhead will pass slightly north of your fire at 1500.

3. What is the anticipated fire behavior? What precautions should be taken?

PROBLEM I

School Solution

Initial Attack Crew take a belt weather kit with them.

Exercise #1.

Slow upslope spread because of east wind. Very little lateral spread. Watch for spots below you, if you get any torching. Request spot weather forecast. Safety would be a factor only with wind shift or spotting.

Exercise #2.

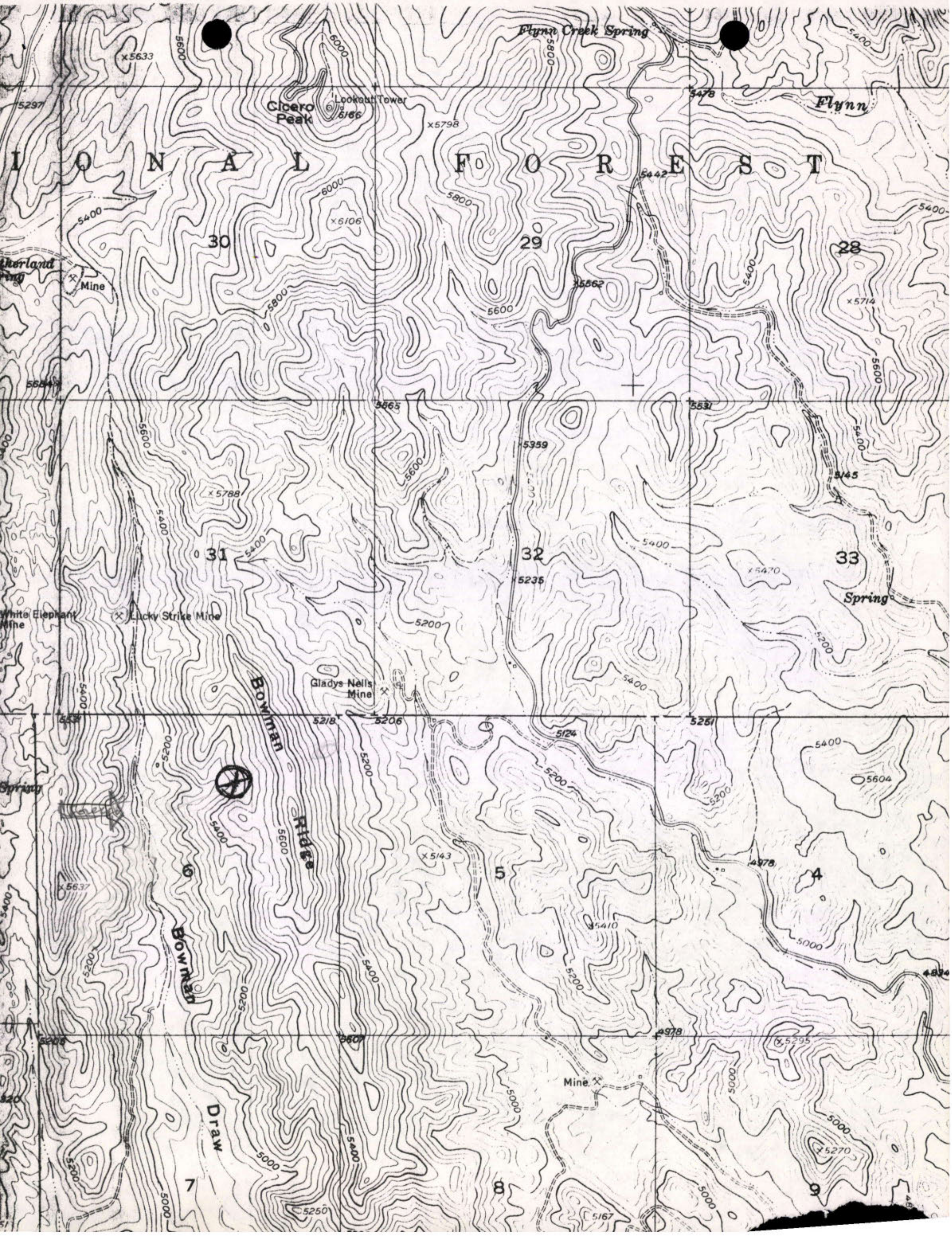
Fire will continue upslope spread until thunderheads arrive. Dust devils apparent on west benches of ridge, can intensify spotting. Shift in wind to the west and intensification of burning on fire head as thunderheads develop. Ask Cicero Peak Lookout to keep you posted on thunderhead dvelopment and arrival. Post local lookout to watch for spotting around fire. Notify all crews of escape route needs and which edge of fire will be dangerous. Caution against frontal attack after 1430. Maintain communications with all crews.

Exercise #3.

Fire will run to ridge top with increased winds from west with spotting over top of ridge. As thunderhead moves eastward, southern flank will become the head. As thunderhead continues east, west flank will become active.

There is a possibility of spots on east side of ridge making a run to top from east to west with eastward passage of thunderstorm. If crews were on ridge top, they could be in danger.

If a strong convection column develops as main fire makes run up to the ridge, any spots on east side of the ridge will make a run up slope to west regardless of thunderstorm activity. Pull crews off east and south side and work them on the north and west side.



Flynn Creek Spring
Flynn
Cicero Peak
Lookout Tower
I O N A L F O R E S T
30
29
28
Mine
31
32
33
White Elephant Mine
Lucky Strike Mine
Spring
Gladys Nells Mine
Bowman Ridge
6
5
4
Bowman Draw
Mine
7
8
9

Course F-1a

INTERMEDIATE FIRE BEHAVIOR

U. S. Forest Service - R-2

FINAL EXAMINATION

Instructions

1. On the yellow and black Trainer-Tester Response Card, Z6b, write:

   Your name in the name block
   Your home unit in the instructor block
   F-1a in the course block

2. Read the examination questions carefully. For each question, there is only one answer that is both true and complete. Select what you think is the best answer (a, b, or c) and erase the black spot on the response card under the letter of your choice.

   If you uncover an R, you have the right answer-- go on to the next question.

   If you uncover an X, you have the wrong answer-- re-read the question and choose another answer. Keep erasing until you uncover an R for each question. Try to get the R the first time, since the best score is the one with the fewest erasures.

3. If you have any questions regarding the test, raise your hand for instructor assistance.

READ EACH QUESTION CAREFULLY AND BE SURE YOU UNDERSTAND IT. BEFORE ERASING ON THE RESPONSE CARD, CHECK TO BE SURE THAT THE QUESTION NUMBER CORRESPONDS WITH THE TEST CARD NUMBER.

1. Which of these would normally cause the worst kind of fire behavior?

   a. Warm front
   b. Occluded front
   c. Cold front

2. Which of the following weather elements always decreases with increasing altitude?

   a. Temperature
   b. Pressure
   c. Relative humidity

3. Fine fuel moisture is useful as an indicator of ignition probability. Spotting from ordinary fire brands:

   a. Is both of the following.
   b. Is unlikely above 25 percent fine fuel moisture.
   c. May reach dangerous proportions below 5 percent fine fuel moisture.

4. A strongly developed convection column is ____________ of a high intensity fire.

   a. An effect.
   b. A cause.
   c. A necessary characteristic.

5. In the absence of a meteorologist on a project fire, the fire behavior officer would usually:

   a. Make his own weather forecast.
   b. Use general forecast received by commercial radio.
   c. Collect weather data from fire area and transmit to the nearest fire weather station for a spot forecast.

6. Assignment of a fire behavior officer would be most important to which of the following fires:

   a. A sector-sized fire in remote alpine fire timber type with 100 line workers and top overhead positions filled.
   b. A multiple crew-sized fire with 75 line workers in brush-grass type near inhabited structures.
   c. A division-sized fire after it had been controlled but is still being mopped up.

7. The combustion process is basically:

   a. The reverse of symbiosis.
   b. The same as photosynthesis.
   c. The reverse of photosynthesis.

8. Fuels, topography, and weather are three factors that:

   a. Determine fire behavior and indicate a fire's potential.
   b. Are necessary for combustion.
   c. Restate the fire triangle.

9. Assuming fuel was constant throughout, where would you be most likely to encounter fire whirls?

   a. Steep slopes.
   b. Benches and ridge tops.
   c. Flat areas and creek bottoms.

10. The most dangerous fire conditions usually exist in the valley bottoms during the period from:

   a. Noon to midnight.
   b. 8 p.m. to 8 a.m.
   c. 8 a.m. to 8 p.m.

11. As a fire runs up a uniform slope, the head of the fire will normally:

   a. Become wider.
   b. Remain constant.
   c. Become more narrow.

12. Fuel moisture content is expressed:

   a. As a percent of oven dry weight.
   b. As a percent of green weight.
   c. In ounces per pound of wood.

13. In a case where there are no gradient winds, which of these canyons (assume all similar size, steepness, etc.) would normally have the strongest, most turbulent winds?

   a. Canyon mouth on west, head on east.
   b. Canyon mouth on southwest, head on northeast.
   c. Canyon mouth on south, head on north.

14. A cold front from the west is forecast to move into your fire area at 1600 hours. As the front passes, the most likely weather occurrence will be:

   a. Steady rain and decreasing fire danger.
   b. Winds shifting from northwest to southwest.
   c. Winds shifting from southwest to northwest.

15. Methods of heat transfer that are <u>major</u> causes of forest fire spread are:

    a. Convection, conduction, and radiation.
    b. Radiation, convection, and spotting.
    c. Radiation, conduction, convection, and spotting.

16. Which one of the following statements is true?

    a. Spotting is less likely with a fractured or sheered convection column.
    b. Glowing combustion begins at higher temperatures than flaming combustion.
    c. Forced convection decreases fire intensity.

17. In a fire suppression organization, the fire behavior officer may advise the fire boss directly and is part of the:

    a. Plans function.
    b. Command function.
    c. Service function.

18. The fire boss has just told you that he hopes to execute a fairly large scale burnout operation in a canyon that runs northeast to southwest (mouth at southwest). Fuel type is mostly cured annual grasses, with scattered light brush and a few pine trees. The 24-hour weather forecast you received an hour ago at 0600 is:

    "Continued clear, warm, and dry. Max. daytime temp. in fire area 95 to 100. Min. humidity this afternoon 6-8 percent. Daytime winds SW 8 to 12, with gusts to 20 in midafternoon. Min. temp. tonight 60-65; max. humidity 25-30 percent; night winds - light to variable."

    The fire boss asks you when the best time would be to start the burnout along the canyon bottom, proceeding downcanyon from NE to SW. Your best answer:

    a. 1500. 3
    b. 2300. 11 P
    c. 1900. 7 P

19. An important property of a fuel bed is particle spacing:

    a. Both horizontally and vertically.
    b. Vertically.
    c. Horizontally.

20. Which quality of a fuel is important to us in understanding fire behavior?

    a. The quantity of heat energy it contains.
    b. Both (a) and (c).
    c. The rate at which the energy is released.

21. In general, which slope exposure provides the most favorable conditions for ignition and spread of wildfire.

    a. South and southwest.
    b. North and northeast.
    c. South and east.

22. During the summer, severe fire conditions usually occur in the thermal belt portion of a slope because of:

    a. Highest average temperature and lowest average relative humidity.
    b. Highest average temperature and highest average relative humidity.
    c. Extreme downslope winds.

23. Adiabatic cooling means:

    a. Cooling due to lifting and evaporation in the air.
    b. Cooling at $5\frac{1}{2}^{o}$ per 500 feet because heat energy is taken from the air.
    c. Cooling due to a decrease in air pressure where no heat energy is lost.

24. Alto-cumulus castellatus clouds observed at 0800 in July in your area are a strong indication of:

    a. Rain within the next 24 hours.
    b. A probable cooling trend.
    c. Thunderstorms that afternoon or evening.

25. Winds produced on a fire by a nearby thunderstorm will:

    a. Blow outward from the general direction of any precipitation or virga.
    b. Blow from the fire towards the thunderstorm because of strong rising currents within the thunderstorm cell.
    c. Not be of importance since a thunderstorm contains mostly vertical currents.

26. Lenticular shaped clouds in the lee of a sharp mountain range indicate:

    a. Thunderstorms will develop rapidly.
    b. Strong downslope winds along the upper lee slopes.
    c. Steady light winds aloft.

27. According to the job description, a fire behavior officer can best do the job if (in addition to other qualifications) he is a:

    a. Meteorologist.
    b. Qualified sector or division boss.
    c. Local man.

28. When extreme fire behavior conditions exist, fires may:

    a. Burn downslope at extreme rates.
    b. Both (a) and (c).
    c. Burn across drainages, burning upslope and downslope.

29. Instability of an air mass can best be judged by:

    a. Well developed convection column fire whirls.
    b. Both (a) and (c).
    c. Clear visibility, dust devils, bumpy flying.

30. Key factors that contribute to extreme fire behavior (blowup conditions) are:

    a. Wind direction and velocity, buildup index, and topographic features.
    b. Position of jet stream over fire, spread index and topographic features.
    c. Fuel amount and dryness, weather factors, and influences of terrain.

~~3~~ 24/30

Prob #2.

WEATHER BUREAU SPOT FORECAST

1530: This is the best I can do without local weather conditions.

Temperature 80° maximum

R. H. 21%

Winds S.W. to W., 20 25 mph, gusts to 40

B. U. I. 181 Spread Index 42

Solution to #2

$$\begin{array}{r} 5 \\ 4 \\ \hline 20 \\ 5 \\ \hline 100 \end{array}$$

1 - See map (rate 20 ch/hr)

2, cold front went through

A. Situation

LOCATION: Western Wyoming

ELEVATION: 9080 feet (See quadrangle map 1 following page)

COVER TYPE: Conifer Forest - Mostly Lodgepole pine of all age classes, moderately stocked. Area was tie hacked in the early days and some logging has occurred recently. Slash areas are in all stages of deterioration.

The ground cover is bunch grass in the openings and moderate to heavy dead fall under the stands. The rate of spread and resistance to control in the area is medium - high.

TOPOGRAPHY: Gentle to steep with occasional lava outcrops. All of the area is a south exposure.

WEATHER: It is August 20. Measurable rainfall has not occurred since June 15. The buildup index has been in extreme for 21 days. Spread has been fluctuating from low to extreme. This is the expected fire weather for the time of the year.

B. The Fire

The aerial patrol reports a smoke on 6 mile creek at 1500. You start for the fire with your crew and arrive at 1530. When you arrive at the fire it is 8 acres in size and spreading in a N.E. direction. These slides show what the fuels look like and a general picture of the area.

While you are enroute to the fire, you ask by radio for a special forecast for the 6 mile area. Just as you arrive you get the Weather Bureau report.

Handout #1

15 Minute Exercise

Exercise No. 1 - Based on the present weather, fuel and topography, sketch on Map I the probable fire area at 2200 on 8/20 from starting point X.

Question: Explain your reasoning for your sketch of the fire size. You are not concerned with suppression activities.

Handout After The

Problem Is Over

Answer - Exercise No. 2:

Cold front has passed over the fire area. Note the 90^{o} shift of wind and drop in temperature from the day before. The fire will not increase in size from the day. Some ground creep may occur in duff area, and smoldering of the heavy fuel. The fine fuels will respond quickly to the higher humidity and will not burn.

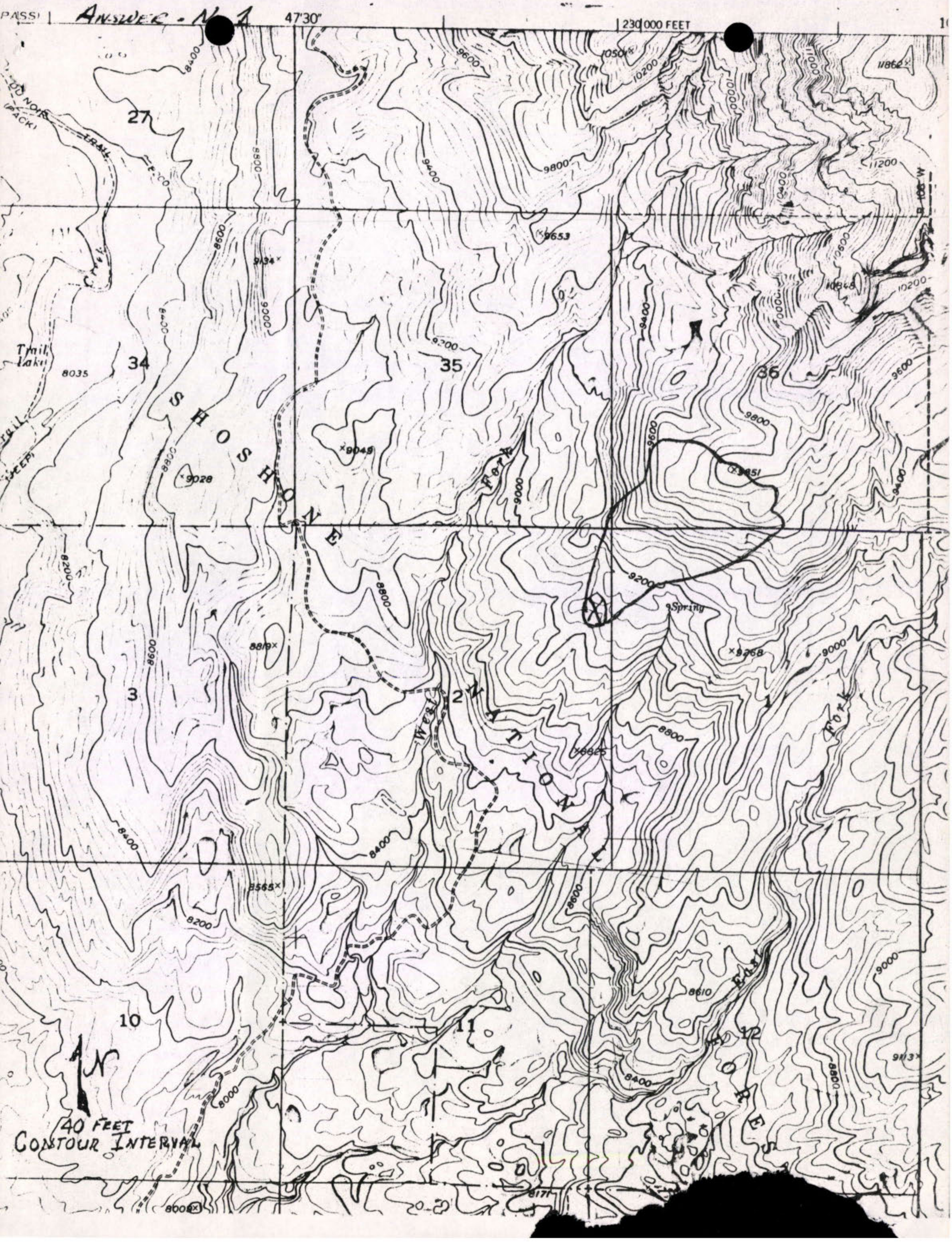
Handout After Problem

Is Over

Answer - Exercise No. 1:

The fire burned about 178 acres in moderate fuels on a gentle slope. Spotting was about 1/4 to 1/3 mile ahead of the main fire with the wind at 20 mph and R.H. of 21%. See the attached map.

ANSWER - No 1


47'30"
230 000 FEET
27
34
35
36
3
2
1
10
11
12
SHOSHONE
NATIONAL
FORES
Trail Lake
8035
Spring
West Fork
Fork
East
9028
9049
9653
9134
8819
8625
9268
8610
8565
9113
8171
N
40 FEET
CONTOUR INTERVAL


PASSI
47'30"
230 000 FEET
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Trail Lake
8035
9028
9049
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9268
8825
8819
8565
8610
11862
11200
10200
9800
9600
9400
9000
8800
8600
8400
8200
8000
Trail
Creek
Fork
East
West
Spring
S H O S H O N E
N A T I O N A L
F O R E S
N
40 FEET
CONTOUR INTERVAL

Handout #2

10 Minute Exercise

Exercise 2 - It is now 0500 on 8/21. The fire has laid down and has not moved since 2400. The current weather based upon information from the fire area:

Temperature - 58° and dropping slightly

R. H. 35-42, wind N. 8-10 mph

Estimated B.U.I. 181. Estimated spread Index 7.

Question: What has occurred since the fire started yesterday? What is the expected size of the fire at 2000 hours today? Draw in on Map 2.

Fire Behavior Problem 3

School Solution - As we discussed, you do not send crews down a chute or draw when you do not have a tie on. The school solution then would be to build line from Sector B, spacing your crews out and burning out as sections of line are completed.

1. As the heat builds up in the morning, increasing hot runs uphill can be expected. Upslope, upcanyon winds will assist these runs. Winds over ridges will cause gustiness on lee slopes causing trouble and spotting. Spot fires could build and make runs. The steep topography will assist these runs.

2. Keeping escape routes is required. Always tie to an established point and work from there. Post lookouts, keep everyone in communication. When you are in a dangerous situation such as this and cannot reach the Line Organization, you can change strategy.

Fire Behavior Problem #3

Synopsis

This is the second day of the 500 acre Gato Creek fire on the Rio Grande National Forest. You have been assigned as a Sector Boss on Sector A. You will be given standard instructions and a map showing your sector. In addition, a short helicopter ride will be given you before you go on the line to familiarize you with your sector.

Today's date is September 10 and no appreciable moisture has been received since July 30. The Del Norte Fire Weather Station indicates the following conditions at 1400 September 9; RH 15%, Dry Bulb 90°, Wind SW 5 MPH, BUI 150.

Please prepare written responses to each handout question.

Question 1: What fire behavior factors do you anticipate on this fire?

a. Sector A will most likely burn out or run to ridge top (flat area)

Sector Boss Instructions

9/10

Sector A - First Shift

Crew Assignments - 25 Blackhats - Johnson
25 Kyle I - Williams
25 Pine Ridge I - Smith
25 Pine Ridge II - Watson

Instructions

Tool your men for rough hand line building with burn out following.

Send two crews to bottom of creek and build fire line to west linking up with Sector B. Have two crews build hand line from junction of Sector C and Sector A to the bottom of the creek. When your line is complete, begin burning out. See map attached. Keep lookout for spot fires outside of your line.

Bring tools into landing at end of shift for pickup and sharpening. Report to Plans for debriefing at 1800.

GATO CREEK FIRE SAFETY NEWS - 9/10

TO ALL FIRE OVERHEAD:

Congratulations! Your SAFETY RECORD to date has been very commendable. In spite of very hazardous conditions, there have been no serious injuries on the Gato Creek Fire. To date, there have been three men disabled - one by a rolling rock, one due to an eye injury caused by running a branch into it, and another because of an insect flying into his ear.

However, with the fatigue factor now entering the picture, a danger of increasing accidents is more present. It is up to you, the overhead, from the Strawboss up to the Division Boss, to keep accidents from occurring. You are directly responsible for the safety of your men. <u>You cannot delegate this responsibility</u>.

FIRELINE SAFETY

The greatest fireline hazard on this fire is from falling snags, rolling rocks, and rolling logs. Be alert to these dangers. Keep lookouts posted for these dangers.

Make certain that every member of your crew knows his immediate boss.

Always have escape routes planned in advance. Remember that a burned-out area is the safest area during blowups.

Be careful of smoke inhalation.

Have your men drink water sparingly and use plenty of salt with their meals.

Immediately release all unsafe workers.

TRANSPORTATION

Do not transport men and tools in the same vehicle. Use your pickup for tools when you have trucks for men.

Designate one man in each truckload of men to insist upon the following:

a. Tools are not being carried with men.
b. Men are seated when truck is traveling.
c. Tailgates, or adequate roping, are used.

Truck drivers must keep a safe distance between vehicles because of smoke limiting visibility.

When traveling through burned areas, one man in the front with the driver must watch for dangerous snags and rolling material.

Depressing headlights, when traveling at night, often increases the visibility in smoky areas.

KEEP IT [illegible]

Fire Behavior Forecast

Gato Creek Fire - Day Shift

General Forecast

This fire should be expected to pick up and move by 1000 a.m. Winds will be light, gusty, and variable in the morning, becoming Southwest somewhat stronger in the afternoon. Upslope winds can be expected on south and east facing slopes by 1000 and upcanyon winds in south and east-facing drainages by 1100. Humidities will remain low, 15 - 20%. Temperature 85 - 90°, Wind SW 10-15 MPH over ridges.

Specific Forecast

Sector A - Upslope winds will be noticeable on all south facing slopes by 1000 - 1100. Winds will be light southwesterly across the ridges this morning, but will increase to 15 MPH from southwest around noon. Winds across ridges may switch back to southerly after 1600, but don't count on it. Firing crews should expect wind eddies and erratic fire behavior. Crews should check wind directions carefully in advance of firing operations on this section of line.

Tice 2100 9/9

FIRE BEHAVIOR PROBLEM #3

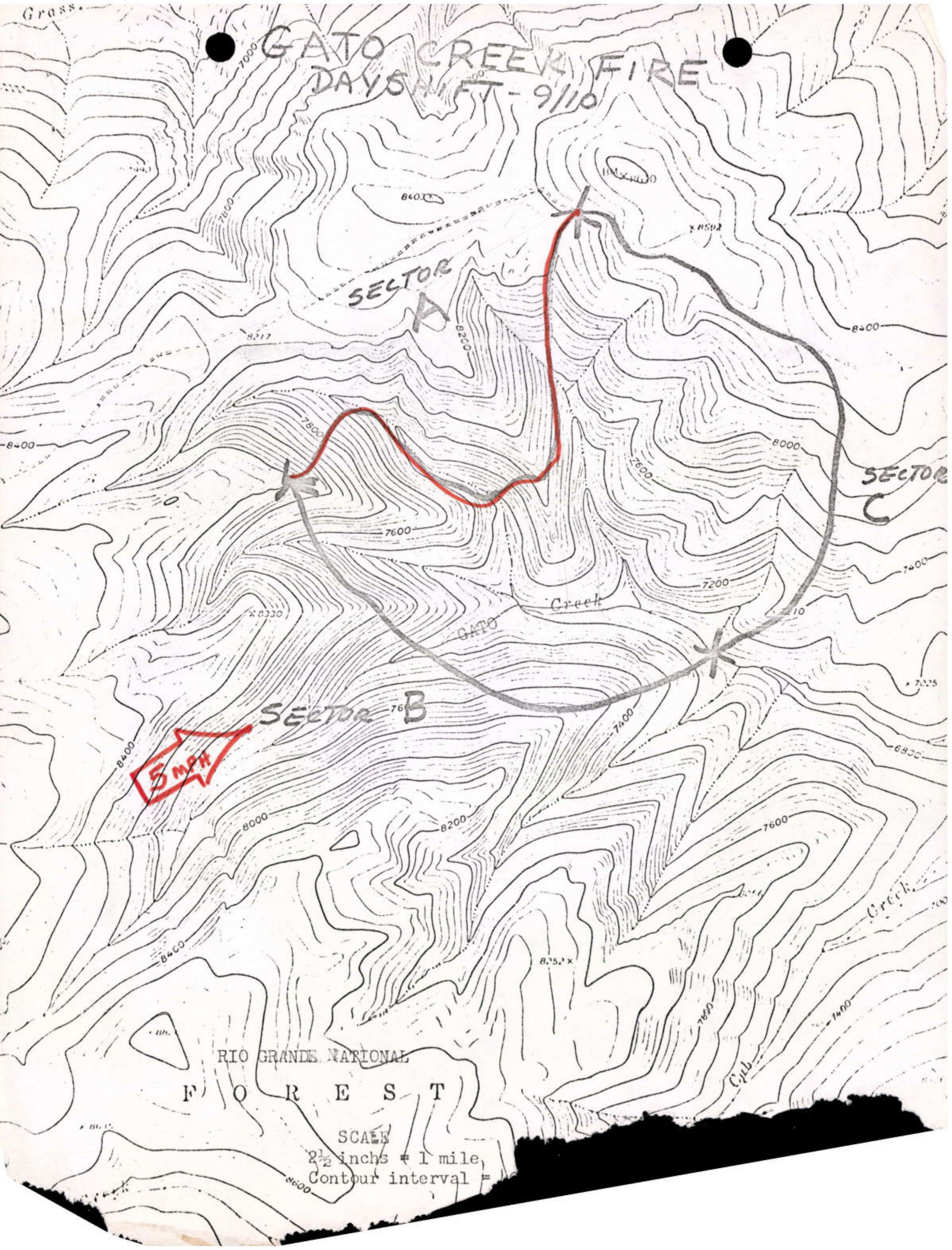
Handout II

2. What safety factors do you anticipate?

(a) steep slopes + very hazardous fuels
(b) no good escape routes available
(c) Too risky to take men into sector A

3. You are unable to contact the Line Boss or Fire Boss. What do you do in this case?

Do not take men into Sector A.
under these safety conditions


GATO CREEK FIRE
DAYSHIFT - 9/10
SECTOR A
SECTOR B
SECTOR C
5 MPH
Gato Creek
Grass
RIO GRANDE NATIONAL
F O R E S T
SCALE
2½ inchs = 1 mile
Contour interval =

U.S.D.A. – Forest Service

INSTRUCTOR'S LESSON PLAN

COURSE Immediate Fire Behavior
LESSON Combustion Process
START & STOP TIMES 0930 - 1030
METHOD OF INSTRUCTION Lecture
PLACE Fort Collins, Colorado
DATE March 16, 1971
OBJECTIVE Give fundamentals of combustion process

INSTRUCTOR Robert W. Tice
FILE NO. 5100 - Fire Control Training
NO. ASSISTANTS 2
NO. IN AUDIENCE 60
TRAINING AIDS Carousel Projector

TIME	LESSON OUTLINE	AIDS & CUES
	Gentlemen, I am passing out a box of matches. Would each of you take two matches and lay them in front of you. Do not strike the matches until I tell you.	Pass out two matches each.
		Turn on projector.
	As the matches are being passed out, I would like you to look at this word. The word is TANSTAFL. Can anybody tell me what it means? Well, for the benefit of those who have never seen this word, it means "There Ain't No Such Thing As Free Lunch," so from now on it is up to you to pay attention.	1. TANSTAFL
	During the next two days you will study in detail all of the various factors related to fire behavior. There is nothing mysterious or secret about fire behavior. All of the behavior elements can be separated in three basic factors. These are fuel, weather, and topography.	2. Pumpkin Creek Fire from air. 3. Fuel, weather, topography
	This session this morning is going to deal with fire physics and more specifically the combustion process.	4. Combustion Process
	Would you all pick up one match and look at it. You will notice that it is made of wood. Wood is very stable at normal temperatures. However, because it is an organic compound, it does suffer deterioration at high temperatures. It darkens, it gives off gases and water, becomes less dense, loses strength, and becomes easily ignited. Please strike your match and watch it as it burns.	
	What you are witnessing is the combustion process. By definition, combustion is the release of stored chemical energy by thermal degradation and rapid oxidation. Fire is both a chemical and physical process. It accomplishes rapidly the breaking up of plant substances, or stored energy, into their chemical parts accompanied by release of heat energy. In the case of wildland fires, the energy is stored in plants by photosynthesis.	5. Chemical Physical Process
	Most of you are probably familiar with photosynthesis but let's review.	

TIME	LESSON OUTLINE	AIDS & CUES
	PHOTOSYNTHESIS	
	$CO_2 + H_2O$ + sun energy = plant tissues plus oxygen.	6. Photosynthesis
	By this process the energy that comes originally from the sun is stored in the plant tissue.	
	Wood which is a plant tissue is very stable at normal temperatures. However, because it is an organic compound it does suffer deterioration at higher temperatures. Combustion then is the release or reversal of the storing process of photosynthesis.	
	COMBUSTION	7. Combustion
	Plant tissue + oxygen + heat = carbon dioxide + water + energy.	
	Please note that plant tissue is fuel so we have the three basic elements of the fire triangle; fuel, oxygen, and heat.	8. Fire triangle
	I have talked about what happens in combustion, now let's look at how the combustion process works.	
	In woody fuels, there are three parts of combustion, although they overlap somewhat and all exist at the same time in the moving forest fire. These three phases are precombustion, ignition, and glowing combustion. I will take each of them separately.	9. Combustion
	1. Precombustion - This is the preheating, distillation, and pyrolysis phase. This is the phase where the fuels ahead of the flame front are heated, dried, and gases given off. These precombustion processes generally take place at temperatures below 540° F.	10. Precombustion
	The physical and chemical changes that take place are complex. For practical purposes we can greatly simplify and say that during this stage the fuel begins changing from solid and liquid form to gas, fuel moisture is lost as water vapor and volatiles in the fuel are released as gas. Cellulose starts to break down.	11. Drum Heating 12. Drum spouting vapor
	2. Ignition and flaming combustion phase - From 540° to 930° F., ignition and flaming combustion take place. Ignition might be regarded as a link between the first or precombustion phase and the second or combustion phase. Ignition may also be regarded as the beginning of that part of the combustion process in which oxidation occurs. Breakdown of cellulose is accelerated. This breakdown provides additional volatiles which may add to flaming combustion. The flames seen over a forest fire or any fire are the burning gases which are given	13. Ignition & flaming combustion

TIME	LESSON OUTLINE	AIDS & CUES
	off and which give invisible water vapor and carbon dioxide as the main combustion products. Flaming combustion takes place in the atmosphere around the fuel not in the fuel itself. Flaming combustion is the burning or oxidation of the gases released from the fuel. If burning is not complete, some of the gaseous substances will condense without being burned and remain suspended as small droplets of liquid or solids over the fire. These condensed substances are the familiar smoke that accompanies most fires. Some of the water vapor may also condense and give the smoke a whitish appearance.	14. Fire at Night 15. Torching Tree
	3. Glowing Combustion - In the third and final combustion phase, the charcoal left from the second phase is burned and leaves a small amount of ash. About 930° F., direct oxidation of the charcoal surface can occur rapidly enough to emit a glow. In this phase the fuel is burned as a solid, with oxidation taking place on the surface of the charcoal. Two things are necessary for this glowing combustion, temperature (930° F.) and direct exposure to oxygen.	16. Glowing Combustion 17. Burning Scattered Fuel
	The three phases of combustion, that is the preheating, flaming, and glowing combustion can occur together. Glowing combustion usually continues after flaming combustion has ceased. The three parts of combustion can be plainly seen in a moving fire. First is the zone in which the leaves and grass curl and scorch as they are preheated by the incoming flames. Next is the fire zone of burning gases. Following the flame is the third but less conspicuous zone of burning charcoal.	18. Grass Fire
	<u>Products of Combustion</u>	
	Heat is the most important product of combustion. It is the main link that sustains combustion as a chain reaction. The heat of combustion has a profound influence on fire behavior because it enables the fire to set it's own weather pattern to the drafts that are created and by drying and preheating the fuels ahead, which in turn increases the energy output and the rate of spread.	19. Fire Closeup
	Would you all please light your second match. We have talked about the heat necessary to start a fire, preheating and ignition. In addition to the heat necessary to start a fire, it is equally important to have a continuous source of heat if the fire is to continue and spread. Using the match as an example, after the chemicals of the match head have flared and exhausted themselves, the job of supplying input heat for the giving off of vapors is taken over by the flame of the burning vapors. This heat goes off into the atmosphere when the match is held upright, preheating decreases, vapors disappear and the match gradually goes out for lack of fuel.	20. Match

TIME	LESSON OUTLINE	AIDS & CUES
	If the match head is tilted downward so the flame surrounds the fresh wood of the match, input heat from the flame maintains the supply of fuel (by producing vapors and gases) and the fire spreads up around the match stick. This difference in the match's behavior can serve to illustrate several principals of fire behavior, but it's most important application to us now is that combustion is a chain reaction process and must have continuous input heat to the fuels in order to sustain itself.	
	The chemical composition of forest fuels varies, but all of them give off about the same amount of heat energy when burned, about 8,000-9,000 B.T.U.'s per pound. The resins and waxes in forest fuels give off 1/2 - 2/3 more energy per pound. About 15,000 B.T.U.'s. Some other characteristics of wood, other than total heat, are ease of ignition and persistent burning.	21. Chem. Comp.
	Some wood, as you know, is easy to ignite such as cedar, while others, such as oak, are very difficult to ignite. In pitchwood, we find very persistent burning; it is very hot and hard to extinguish. Bark has essentially the same heating value of wood. Some bark has shown outstanding insulating propertys and is hard to light. Heavy fir bark, for example, is hard to light without a great deal of heat. Other barks, such as birch bark will ignite even when wet.	22. Camp Fire
	<u>Moisture in Fuels</u>	
	All parts of living plants contain moisture. Some of it is lost after death but never all of it, under natural conditions. Water occurs in plant cells both as free water and bound water. Free water is bound inside the cells and in the inter-cellular spaces. Bound water is absorbed into the fibers of the cell wall. Bound water has a higher boiling point than free water and this requires a greater amount of heat to cause ignition.	23. Fuel Moisture
	Free water is given off as a vapor during the preheating phase. If fuels are not already dry when heat is applied, moisture is given off until it is gone. Continued heating results in volatiles and gases being given off. This explains why, in part, fires start easier on hot days. Temperatures of 170° at ground level have been recorded. The fuel temperature is already part way toward the 400° to 600° needed to preheat the fuel so that it can give off vapors.	24. Fuel Moisture
	Once the fuels are preheated and the vapors and gases are being given off, then it is necessary that we have the right supply of oxygen. There must be the right quantity and it must be properly mixed with the vapors and gases of the fuel. In most forest fuel situations, this is automatically supplied from the air surrounding the fuel. Lastly there must be a continuous supply of oxygen to the fire in order to sustain combustion. A continuous supply is also almost automatic for forest fuels. However, if there is a wind blowing it will supply more oxygen and the fire will burn more intensely.	25. Forest Fire

TIME	LESSON OUTLINE	AIDS & CUES
	Let's review combustion:	
	A. Plants are formed by photosynthesis. B. Combustion is the breakdown or reverse of this process. C. There are three elementary ways this breakdown or oxidation occurs:	26. Growing Plants
	1. Precombustion - moisture is evaporated. Part of the fuel is released as a gas, cellulose starts to break down.	27. Fire
	2. Ignition occurs and flaming combustion begins. Flaming combustion is the rapid oxidation of the flammable gases given off by the fuel.	
	3. Glowing combustion. At 930° + in direct contact with oxygen, the carbon or charcoal is oxidizing rapidly enough to glow. This is glowing combustion.	
	This carbon must be oxidized as a solid because it's melting and boiling points are higher than the heat of combustion.	
	Most of our present day fire retardants work by adding mineral salts to the fuel. This causes more of the fuel to remain in solid form. This results in more glowing combustion and less flaming combustion.	28. Airtanker Air Drop.
	As I stated in the beginning, the combustion process is a part of the three main fire behavior factors. It is concerned with fuel mainly, but weather and topography are also involved. These factors always act together and upon each other.	29. Fire on Slope
	Learning the details of these factors will be somewhat like learning the alphabet so that you can later learn to read.	30. Fire & Smoke
	Remember that the individual items you study are only details in a much larger, more complicated framework.	
	Do You Have Any Questions?	31. The Very Living End

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INSTRUCTOR'S LESSON PLAN

SUBJECT: Int. Fire Behavior
INSTRUCTOR: Bob Miller
TITLE OF LESSON: Heat Transfer
FILE NO. 5120
DATE: 3/16/71
LENGTH OF LESSON: 55 55 Minutes
NO. ASSISTANTS:
METHOD OF INSTRUCTION:
PLACE: Rocky Mountain F. & Res.
TRAINING AIDS:
NUMBER IN AUDIENCE:
OBJECTIVE:

TIME	LESSON OUTLINE	AIDS & CUES
1050	I. INTRODUCTION	

JUST WHAT IS HEAT TRANSFER?

IT IS THE TRANSFER OF HEAT - OR GETTING HEAT FROM HERE TO THERE.

WHAT DOES THIS HAVE TO DO WITH FIREFIGHTING? A BURNING FIRE TRANSFERS HEAT - IF WE UNDERSTAND HEAT TRANSFER, WE WILL BETTER UNDERSTAND FIRE AND FIREFIGHTING.

ALL RIGHT, BUT WHAT DO WE MEAN BY "HEAT"? HEAT IS A FORM OF ENERGY WHICH COMES ORIGINALLY FROM THE SUN. OTHER FORMS ARE CHEMICAL ENERGY, KINETIC (MOTION) ENERGY, ELECTRICIAL ENERGY, ETC.

LET'S SEE HOW IT ALL WORKS.

IN OUR DISCUSSION ON COMBUSTION, HEAT WAS INVOLVED IN TWO WAYS: 1. IT WAS REQUIRED TO BRING THE FUEL UP TO A TEMPERATURE WHERE COMBUSTION COULD OCCUR.

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	2. HEAT ENERGY WAS A PRODUCT OF COMBUSTION. A CRITICAL CONSIDERATION OF FOREST FIRE BEHAVIOR IS THE HEAT FROM COMBUSTION THAT IS TRANSFERRED TO OTHER FUELS. THIS TRANSFERRED HEAT STARTS THE COMBUSTION PROCESS IN THE NEW FUEL. THE AMOUNT AND SPEED WITH WHICH THE HEAT IS TRANSFERRED IS A MAJOR INFLUENCE ON THE RATE OF FIRE SPREAD.	
	WE NEED TO UNDERSTAND HEAT TRANSFER SO THAT YOU CAN BETTER ESTIMATE RATES OF SPREAD.	
	THERE ARE 4 WAYS THAT HEAT IS TRANSFERRED. THESE ARE: 1. RADIATION 2. CONDUCTION 3. CONVECTION 4. SPOTTING (MASS TRANSPORT)	VU - GRAPH #1
	DISCUSS VU - GRAPH	
	WE WILL CONSIDER EACH OF THESE METHODS OF HEAT TRANSFER, AS IT RELATES TO FIRE BEHAVIOR.	

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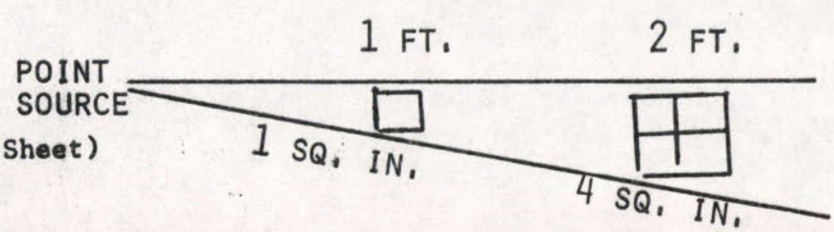
TIME	LESSON OUTLINE	AIDS & CUES
1055	2. <u>RADIATION</u>	
	THE SUN IS THE SOURCE OF ALL ENERGY. THIS ENERGY REACHES THE EARTH BY RADIATION. THIS SAME METHOD OF HEAT TRANSFER WORKS WITH FOREST FIRES, SO WE CAN USE THIS KNOWLEDGE IN FIREFIGHTING.	
	RADIATION IS THE PROCESS BY WHICH HEAT IS TRANSMITTED THROUGH SPACE WITHOUT THE AID OF EITHER MOLECULAR ACTION OR MASS TRANSFER WITHIN THE INTERVENING SPACE. RADIATION ENERGY MOVES FROM THE WARMER MEDIUM TO THE COOLER ONE.	
	THIS RADIANT ENERGY TRAVELS IN STRAIGHT LINES FROM THE SOURCE, AND THE AMOUNT RECEIVED OVER ANY GIVEN SURFACE AREA DECREASES INVERSELY WITH THE SQUARE OF THE DISTANCE FROM THE HEAT SOURCE. FOR INSTANCE THE AMOUNT OF ENERGY RECEIVED PER UNIT AREA IS 1/4TH AS GREAT AT A DISTANCE OF 2 FT. AS AT A DISTANCE OF 1 FT. FROM THE SOURCE.	VU - GRAPH #2



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TIME	LESSON OUTLINE	AIDS & CUES

THE EARTH'S SURFACE IS COVERED WITH VARYING MATERIALS WHICH DIFFER RADICALLY IN THEIR ABILITY TO ABSORB RADIANT ENERGY.

As Examples:

Material	Absorpivity (1.0 = 100%)
LAMP BLACK	.96
PINE FOREST	.86
DRY SAND	.82
DRY GRASS	.68
ALUMINUM FOIL	.15
NEW SNOW	.13

Vu - Graph #3

IN GENERAL, DARK, ROUGH SURFACES ABSORB HEAT RADIATIONS AND SMOOTH, BRIGHT SURFACES REFLECT THEM.

BODIES WHICH ABSORB RADIATION READILY ALSO RADIATE IT READILY. A GOOD ABSORBER OF HEAT IS A GOOD RADIATOR. A DARK, ROUGH BODY WILL RADIATE MORE HEAT THAN A BRIGHT BODY AT THE SAME TEMPERATURE. THIS RELATIONSHIP IS BASIC TO AN UNDERSTANDING OF SOME OF THE CAUSES OF LOCAL WEATHER CONDITIONS WHICH WE SHALL DISCUSS LATER.

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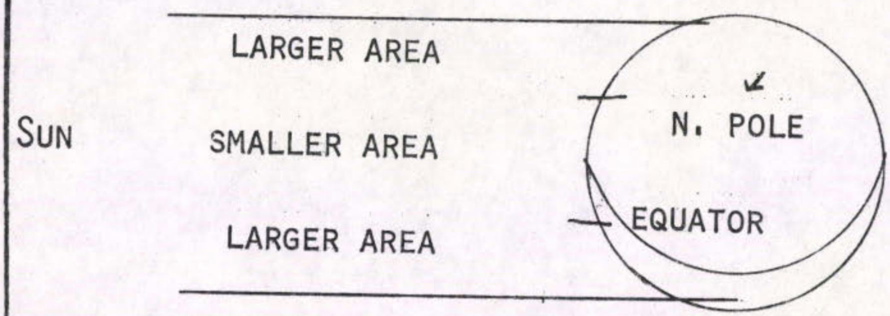
	THE RATE OF RADIATION IS ALSO DEPENDENT ON THE AMOUNT OF SURFACE AREA AND ON THE TEMPERATURE OF THE RADIATING BODY. THE LARGER THE SURFACE AREA AND/OR THE HIGHER THE TEMPERATURE THE GREATER THE RADIATION.	
	ABSORPTION OF RADIANT ENERGY BY VEGETATION INCREASE THE TEMPERATURE OF SUCH GROWTH AND REDUCES THE TEMPERATURE INCREASE NECESSARY TO PRODUCE IGNITION AND, COMBUSTION.	
	RADIATION WILL OFTEN DETERMINE WHETHER WE PLACE A FIRE LINE AT THE FIRE'S EDGE OR WHETHER WE FALL BACK A FEW FEET WHERE IT IS COOLER. ALSO, WE FIND THAT OUR FIRE LINE WIDTH IS DETERMINED BY THE AMOUNT OF RADIATION ENERGY WE MUST OVER-COME.	
	TOPOGRAPHY - ASPECTS - ANGLE OF SLOPE, AND RELATED TOPOGRAPHIC FEATURES ALSO VARY THE AMOUNT OF THE SUN'S ENERGY THAT THE EARTH ABSORBS ON A SMALLER SCALE THESE ALSO HAVE A RELATION TO HEAT RADIATION FROM FOREST FIRES.	

TIME | LESSON OUTLINE | AIDS & CUES

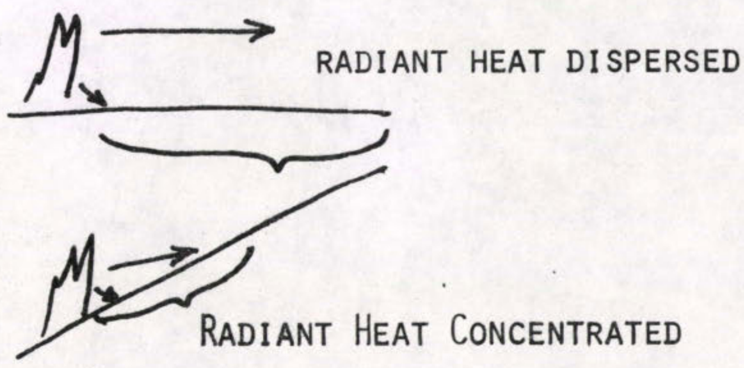
IF YOU FACE A LARGER HEAT SOURCE, SAY A FLAME FRONT, THE REDUCTION OF ENERGY IS NOT AS MUCH AS FROM A SINGLE POINT SOURCE - MORE GETS THROUGH SINCE THERE IS A LARGER NUMBER OF POINTS AND THEREFORE MORE HEAT BEING RADIATED.

SINCE EARTH IS TILTED ON ITS AXIS, SOME OF THE SUN'S RADIATION HITS THE EARTH SQUARELY, NEAR THE EQUATOR, AND SOME HITS THE EARTH AT AN ANGLE, NEARER THE POLES.



VU - GRAPH #4

THIS MEANS THE PORTION OF THE EARTH NEARER THE EQUATOR BECOMES PROPORTIONATELY MUCH WARMER THAN THE POLAR AREA. THIS UNEVEN BALANCE OF HEAT TRIGGERS AIR MOVEMENTS (WHICH WE CALL "WEATHER"). IT WILL BE COVERED IN CONSIDERABLE DETAIL LATER.

TIME	LESSON OUTLINE	AIDS & CUES
	THE EARTH AS A WHOLE RECEIVES EVERY MINUTE AS MUCH ENERGY AS MANKIND USES IN A WHOLE YEAR. THIS AMOUNTS TO AN ANNUAL ACCUMULATION OF ABOUT 10 BILLION CALORIES PER ACRE IN A CONIFER, FOREST OR THE ENERGY EQUIVALENT OF ABOUT 310 GALLONS OF GASOLINE.	
	RADIATION PASSES FREELY THROUGH SPACE. WHEN IT FALLS UPON MATTER, SOME RADIATION IS REFLECTED, SOME ABSORBED, AND SOME MAY BE TRANSMITTED. THE EXTENT TO WHICH THESE DIFFERENT ITEMS OCCUR DEPENDS ON THE CHARACTERISTICS OF THE BODY UPON WHICH THE RADIATION FALLS.	
	MORE ENERGY WILL BE RECEIVED PER UNIT AREA IF THE RECEIVING SURFACE IS PERPENDICULAR TO THE RADIATION THAN IF IT IS AT AN ANGLE.	
		VU - GRAPH #5

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TIME	LESSON OUTLINE	AIDS & CUES
	RADIATION BECOMES IMPORTANT IN WILDFIRE SPREAD PRIMARILY UNDER SPECIAL SITUATIONS, SUCH AS IN VERY NARROW, STEEP-SIDED CANYONS. FLAME CONTACT WITH UNBURNED FUELS AND FIREBRANDS FALLING AHEAD OF THE FIRE APPEAR LIKELY TO BE THE MAIN MECHANISM BY WHICH FIRES SPREAD, PARTICULARLY WHERE WIND IS A FACTOR.	
	THE EARTH'S ATMOSPHERE HAS SEVERAL IMPORTANT EFFECTS ON RADIATION.	
	A. CLOUDS, WHICH ARE SMALL WATER DROPLETS, SCREEN OUT SOLAR RADIATION, REDUCING SURFACE HEATING. AT NIGHT, CLOUDS CAN REFLECT HEAT RE-RADIATED BY THE EARTH BACK TOWARD EARTH, RESULTING IN WARMER NIGHTS.	
	B. ON "CLEAR" DAYS, THE SUN'S RAYS ARE STILL FILTERED OUT BY VARIOUS COMPONENTS OF THE EARTH'S ATMOSPHERE. THE OZONE LAYER OF THE ATMOSPHERE ABSORBS MOST OF THE ULTRAVIOLET RADIATED BY THE SUN. THE VISIBLE LIGHT IN THE BLUE AREA IS SCATTERED, RATHER THAN ABSORBED - THUS MAKING BLUE SKY.	

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	C. AFTER REACHING THE EARTH'S SURFACE, THE VARIOUS ENERGY WAVELENGTHS CAUSE THE EARTH TO WARM UP. THIS HEAT IN TURN IS RE-RADIATED BACK INTO SPACE AS INVISIBLE INFRARED ENERGY. THE INFRARED SCANNER IN THE FIRESCAN AIR-CRAFT "SEES" THIS AND CONVERTS IT TO A VISIBLE IMAGE. IT ALSO SEES FIRES AND OTHER HEAT SOURCES.	
	D. CARBON DIOXIDE IN THE EARTH'S ATMOSPHERE ABSORBS AND RE-RADIATES THIS RE-RADIATED INFRARED BACK TO THE EARTH, FURTHER RAISING THE TEMPERATURE AT THE EARTH'S SURFACE. THIS IS THE SO-CALLED "GREENHOUSE" EFFECT. CARBON DIOXIDE ALLOWS THE SUN'S ENERGY (LARGELY ULTRAVIOLET) TO PASS FREELY, BUT TRAPS SOME OF THE EARTH'S HEAT.	
	SO MUCH FOR <u>RADIATION</u>, ONE OF THE FOUR MAJOR METHODS OF HEAT TRANSFER.	
	NOW THAT WE HAVE <u>RADIATED</u> ALL THAT ENERGY FROM THE SUN TO THE EARTH AND EITHER STORED IT FOR FUTURE USE IN SOME FORM OF FUEL OR USED IT IN	

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	SOME OTHER WAY, WE WILL CONSIDER OTHER METHODS OF HEAT TRANSFER.	
	HEAT ALWAYS FLOWS FROM A WARMER MASS TO A COOLER MASS. THE AMOUNT OF HEAT AN OBJECT HAS IS MEASURED BY A THERMOMETER AND CALLED TEMPERATURE.	
	WHEN A SUBSTANCE IS HEATED UP, THE MOLECULES IN THAT SUBSTANCE BEGIN TO MOVE ABOUT MORE FREELY. THESE MOLECULES ARE ALREADY MOVING BUT THEY BEGIN MOVING FASTER WHEN THEY ARE HEATED UP. IN THE CASE OF A GAS THE MOLECULES MAY MOVE FURTHER APART, CAUSING EXPANSION.	
1115	3. CONDUCTION HEAT IS TRANSFERRED WITHIN SOLIDS, LIQUIDS, AND GASES BY A PROCESS CALLED CONDUCTION. THIS IS THE TRANSFER OF ENERGY FROM PARTICLE TO PARTICLE OF MATTER BY CONTACT AND THROUGH A CONDUCTING MEDIUM BY KINETICS (MOTION).	
	CONDUCTION CAN ALSO TRANSFER ENERGY OTHER THAN HEAT I.E. ELECTRICAL ENERGY, KINETIC ENERGY, ETC.	

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	IN LIQUIDS AND GASES, CONDUCTION IS USUALLY OF LESSER IMPORTANCE THAN CONVECTION BECAUSE OF THE MOVABILITY OF THE LIQUID OR GAS MOLECULES.	
	CONDUCTION CAN BE DEMONSTRATED BY ATTACHING PIECES OF WAX TO A METAL ROD, HEATING ONE END OF THE ROD, AND OBSERVING THE WAX AS IT MELTS AND FALLS FROM THE ROD.	DEMONSTRATION W/COPPER ROD, VICE, ASH TRAY, WAX, AND BLOW TORCH, IF TIME PERMITS.
	SOME SOLIDS ARE GOOD CONDUCTORS; OTHERS ARE POOR CONDUCTORS. THE AMOUNT OF HEAT THAT WILL FLOW BY CONDUCTION THROUGH A PIECE OF MATERIAL DEPENDS ON THE TIME THAT THE HEAT FLOWS, THE TEMPERATURE DIFFERENCE BETWEEN THE HOT AND COLD FACES, THE AREA AND THICKNESS OF THE SUBSTANCE AND NATURE OF THE MATERIAL.	
	THE VALUES HAVE BEEN DETERMINED EXPERIMENTALLY FOR VARIOUS SUBSTANCES. COPPER, WHICH IS A GOOD CONDUCTOR HAS A VALUE OF .0975. WOOD ON THE OTHER HAND HAS AN AVERAGE VALUE OF .0002. IN GENERAL, METALS ARE GOOD CONDUCTORS WHILE NON-	

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METALS ARE POOR CONDUCTORS. VERY POOR CONDUCTORS ARE USED AS INSULATORS. LIQUIDS ARE POOR CONDUCTORS, AND GASES ARE VERY POOR. THE BEST INSULATORS, THEN, ARE SUBSTANCES WHICH IN THEMSELVES ARE POOR CONDUCTORS.

IN SOLIDS, CONDUCTION IS THE ONLY METHOD OF HEAT TRANSFER. IT IS ALSO ONE OF THE MAIN FACTORS LIMITING THE RATE OF BURNING IN HEAVY FUELS, SUCH AS SLASH, LIMBS AND LOGS, ETC. MATERIALS THAT ARE POOR CONDUCTORS OF HEAT (SUCH AS MOST FOREST FUELS) IGNITE MORE READILY THAN DO GOOD CONDUCTORS, BUT THEY BURN MORE SLOWLY.

EXAMPLE - ONE OF THE BEST PLACES FOR SPOT FIRES TO START IS IN PUNKY LOGS, IN SNAGS, AND OTHER SUCH PLACES WHERE A ROUGH SURFACE, OFTEN A DARK COLOR, AND FINELY DIVIDED FUEL PARTICLES PROVIDE AN IDEAL STARTING PLACE FOR FIRES.

BECAUSE OF THE POOR CONDUCTIVITY OF WOOD, <u>CONDUCTION AS SUCH</u> IS NOT A MAJOR FACTOR IN FOREST FIRE SPREAD.

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WE HAVE NOW CONSIDERED TWO OF THE FOUR MEANS OF HEAT TRANSFER:

RADIATION

CONDUCTION

THESE WILL HELP US UNDERSTAND THE REMAINING PROCESSES.

THE PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION MADE SOME INTERESTING DETERMINATIONS OF THE HEAT BALANCE IN A WOOD FUEL FIRE.

	PERCENT	
CONVECTIVE HEAT	61.7	
RADIATION	18.1	
CONDUCTION (INTO GROUND)	4.9	VU - GRAPH #6
HEAT VALUE OF CHARCOAL	1.0	
HEAT VALUE OF UNBURNED COMBUSTION GASES	5.5	
HEAT ACCOUNTED FOR	91.2	
HEAT NOT ACCOUNTED FOR	8.8	
TOTAL HEAT	100.0	

NOTICE THAT NEARLY 2/3 THE HEAT WENT INTO <u>CONVECTION</u>. CONVECTION IS <u>VERY</u> IMPORTANT IN THE SPREAD OF FOREST FIRES.

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1125 4. CONVECTION

WHAT IS CONVECTION, REALLY?

IT IS THE TRANSFER OF HEAT BY THE MOVEMENT OF A GAS OR LIQUID.

THE KEY HERE IS MOVEMENT. THIS IS WHY SOLIDS CAN'T CONVECT.

A FEW EXAMPLES OF CONVECTION MAY HELP US HERE:

1. A HOUSE IS HEATED BY CONVECTION. THE HOT AIR FURNACE TRANSFERS HEAT TO THE INTERIOR OF THE HOUSE.(ALTHOUGH THE AIR IS HEATED AT THE FURNACE BY CONDUCTION). THE DIFFERENCE IN THE AIR'S DENSITY, BECAUSE OF THE DIFFERENCE IN THE AIR'S TEMPERATURE, CAUSES CIRCULATION AND THUS THE WHOLE ROOM IS HEATED.

2. CONVECTION, WITH SOME HELP FROM RADIATION, IS THE MAIN REASON GROUND FIRES ARE TRANSMITTED INTO TREE CROWNS. HOT GASES FROM THE GROUND FIRE BELOW RAISE CANOPY TEMPERATURE TO OR NEAR THE KINDLING POINT. ALTHOUGH CONVECTION INITIATES CROWNING, BOTH CONVECTION

TIME	LESSON OUTLINE	AIDS & CUES

AND RADIATION PREHEAT THE CROWN CANOPY AHEAD OF THE FLAMES. THIS IS PARTICULARLY EVIDENT WHEN A FIRE MOVES UP SLOPE.

TREE CROWNS, DRIED AND PRE-HEATED BY CONVECTION, FROM A GROUND FIRE ARE A DANGER THAT MOST FIRE CONTROL PEOPLE RECOGNIZE. SURFACE FIRES MUST BE COOLED PROMPTLY, AND HOT FUEL MASSES SHOULD BE BROKEN UP TO PREVENT CROWN FIRES.

3. WIND IS CAUSED BY CONVECTION. HEATED AIR EXPANDS, BECOMES LESS DENSE AND MORE BUOYANT AND RISES. THE SPACE BEHIND THIS MOVING AIR IF FILLED WITH COOLER, HEAVIER AIR, AND THE PROCESS GOES ON AND ON. CLOUDS ARE FORMED WHEN THE HEATED AIR COOLS AND MOISTURE CONDENSES.

THE PROCESS OF CONVECTION IS RESPONSIBLE FOR THE MAJOR AIR CIRCULATION PATTERNS OF THE WORLD, WHICH WILL BE DISCUSSED LATER. COLD AIR MOVING FROM THE POLES FLOWS TOWARD THE EQUATOR WHERE IT IS HEATED AND FORCED UPWARD

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	BY MORE COLD AIR. AS IT IS COOLED AGAIN, IT DESCENDS AND THE CYCLE IS COMPLETED.	
	LAND AND SEA BREEZES RESULT FROM THE TEMPERATURE DIFFERENCES BETWEEN LAND AND WATER. DURING THE DAYTIME, THE LAND ORDINARILY HAS A HIGHER TEMPERATURE THAN THE WATER. AIR WARMED BY THE LAND DECREASES IN DENSITY AND WINDS ARE CAUSED AS COOLER, DENSER AIR FROM OVER THE BODY OF WATER MOVES IN TO DISPLACE IT. AT NIGHT, THE REVERSE IS TRUE. THE LAND COOLS MORE RAPIDLY THAN THE WATER. AIR OVER THE WATER IS THUS MADE RELATIVELY WARMER AND LESS DENSE, AND IS DISPLACED BY THE COOLER, DENSER AIR MOVING OUT FROM THE LAND, RESULTING IN OFF-SHORE BREEZES.	VU - GRAPH #7
	CONVECTION IS ALSO DEMONSTRATED BY THE DEVELOPMENT OF CUMULUS CLOUDS. WARM AIR RISES BECAUSE OF LOCAL HEATING. AS ITS TEMPERATURE DECREASES, THE VAPOR IN THE AIR CONDENSES TO FORM CLOUD DROPLETS. THE CONVECTION CYCLE IS COMPLETED BY THE RETURN OF THIS COOLER AIR TO LOWER ELEVATIONS.	VU - GRAPH #8

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	ANOTHER READILY APPARENT EXAMPLE OF THE CONVECTION PROCESS WHICH MOST OF YOU HAVE UNDOUBTEDLY NOTICED IS THE COLUMN OF SMOKE WHICH RISES FROM A FIRE WHEN THE WIND DOES NOT CARRY IT AWAY. THE SHAPE AND CHARACTER OF SMOKE COLUMNS IS A VERY VALUABLE AID IN PREDICTING FIRE BEHAVIOR. CONVECTION IS OF PARTICULAR IMPORTANCE TO THE FOREST-FIRE CONTROL MAN BECAUSE OF STRONG CONVECTION UPDRAFTS OVER A FIRE FRONT CARRYING HEAT TO TREE CROWNS AND OFTEN THROWING FIREBRANDS FAR AHEAD OF THE FIRE FRONT.	
	IN FIRES WE SPEAK OF TWO TYPES OF CONVECTION: FREE CONVECTION AND FORCED CONVECTION.	
	FREE CONVECTION IS WHERE THE CONVECTION IS DUE ONLY TO THE CIRCULATION SET IN MOTION BY THE HEAT OF THE FIRE.	
	FORCED CONVECTION IS WHERE A BLOWER OR IN THE CASE OF FOREST FIRES, THE WIND "FORCES" OXYGEN INTO THE FIRE. THIS SETS THE STAGE FOR HIGH INTENSITY FIRES.	

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EITHER WAY, WHEN CONVECTION GETS GOING IN A BIG WAY, THE FIRE IS ON ITS WAY TO A HIGHER-INTENSITY, PERHAPS LARGE OR EVEN BLOWUP FIRE. FIRE THEN CHANGES FROM TWO-DIMENSIONAL TO THREE-DIMENSIONAL. (LATERAL, HORIZONTAL AND VERTICAL)

ALTHOUGH THE CONVECTION COLUMN ON A LARGE FIRE (WHICH MAY REACH 25,000 OR 35,000 FT. ALTITUDE) HAS BEEN CONSIDERED AS ESSENTIAL TO LARGE, INTENSE FIRE DEVELOPMENT, THERE IS LITTLE ACTUAL EVIDENCE THIS IS TRUE. IN OTHER WORDS, THE CONVECTION COLUMN IS A SYMPTOM OF A LARGE FIRE AND NOT THE CAUSE OF A LARGE FIRE. EXCEPT <u>WHERE SPOTTING OCCURS</u>, THE CONVECTION COLUMN MAY ACTUALLY RETARD THE SPREAD, AS IN LOGGING SLASH DISPOSAL FIRES BY DISPERSING HEAT.

SO FAR, WE HAVE CONSIDERED THESE METHODS OF HEAT TRANSFER:

RADIATION
CONDUCTION
CONVECTION

THE ONLY METHOD LEFT IS MASS TRANSPORT OR SPOTTING.

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1140	5. SPOTTING ONE REASON CONVECTION IS SO IMPORTANT TO FIRE SPREAD IS BECAUSE OF ITS RELATIONSHIP WITH OUR 4TH TYPE OF HEAT TRANSFER, MASS TRANSPORT OR SPOTTING. SPOTTING IS THE RELOCATION OF A HEAT SOURCE THROUGH PHYSICAL MOVEMENT. THE HEAT SOURCE COULD BE HOT CARBON PARTICLES FROM AN EXHAUST, IT COULD BE EMBERS OR FLAMING FIREBRANDS FROM A FIRE. THE FORCE THAT RE-LOCATES THE HEAT SOURCE IS FREQUENTLY CONVECTION. EMBERS ARE CARRIED INTO THE AIR BY THE CONVECTION COLUMN. WHEN THEY FALL BACK INTO FOREST FUELS A NEW FIRE MAY START. SPOTTING IS MORE LIKELY FROM A FRACTURED OR SHEARED CONVECTION COLUMN. GRAVITY AND WIND MAY ALSO CAUSE SPOTTING BUT A LARGE NUMBER OF SPOTS OR LONG DISTANCE SPOTTING IS ALMOST ALWAYS THE RESULT OF STRONG CONVECTION ACTION.	U - GRAPH #9

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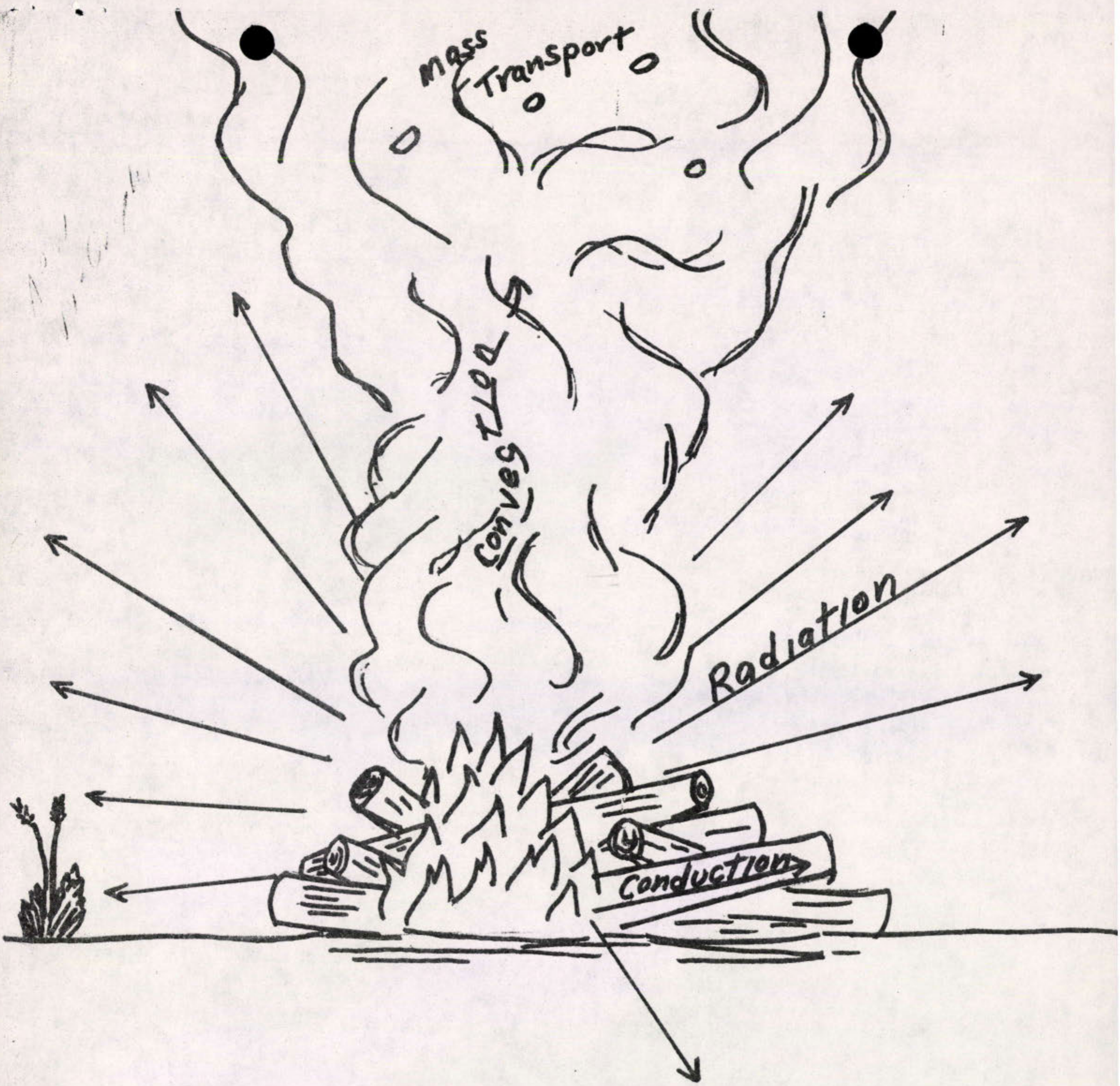
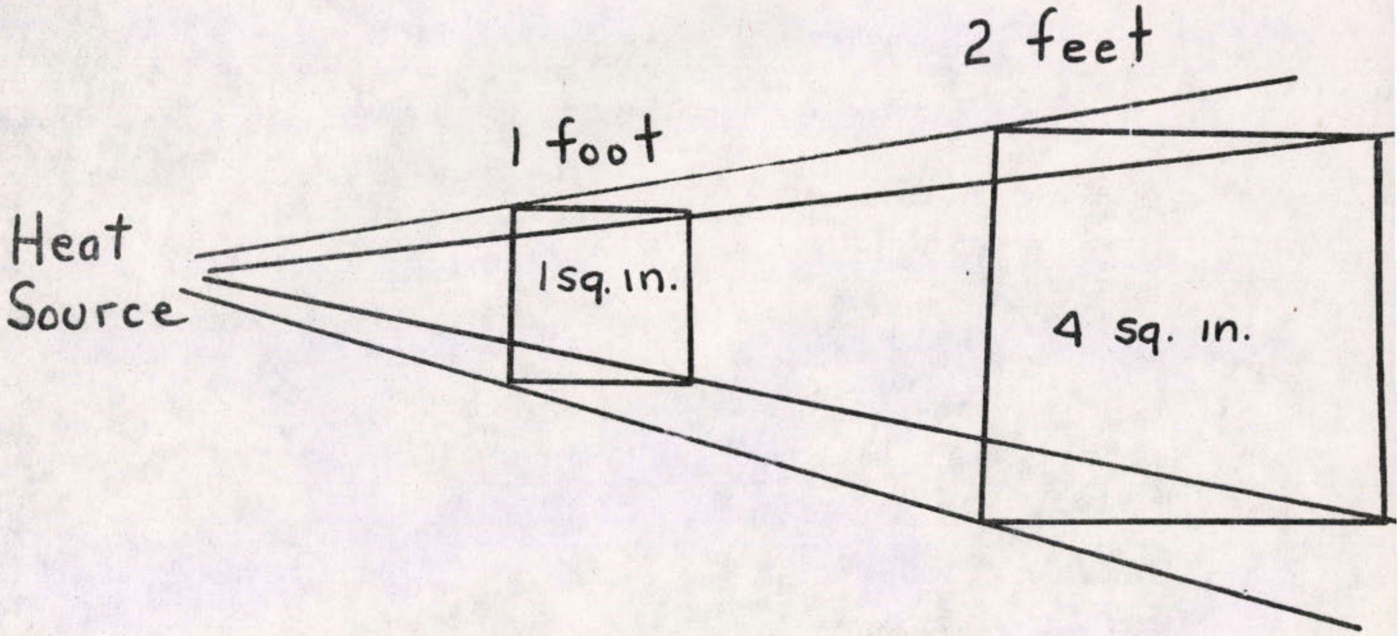
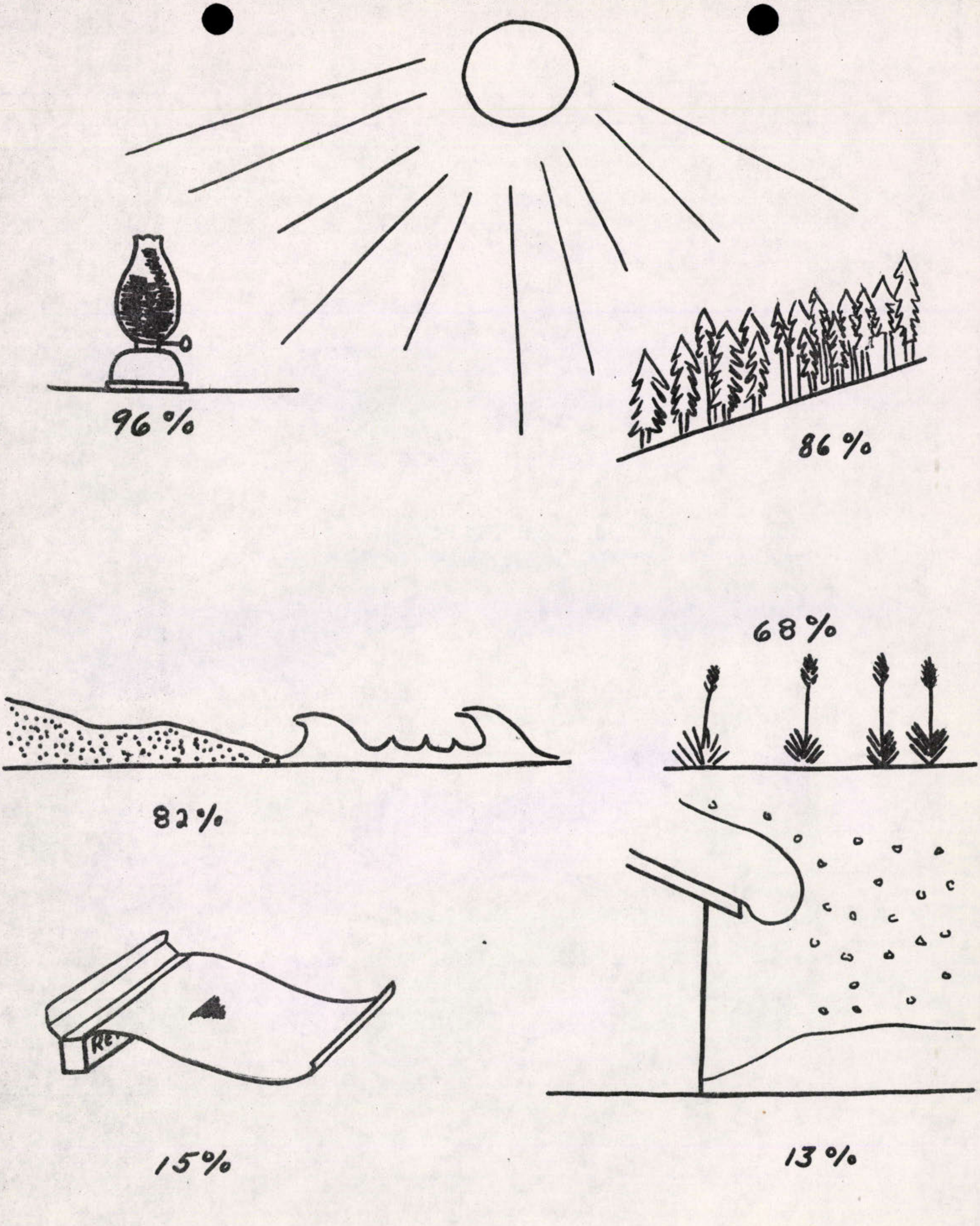
	SPOTTING IS FREQUENTLY A MAJOR FACTOR IN FIRE SPREAD.	
	SPOTTING MAY OCCUR SEVERAL MILES BEYOND THE MAIN FIRE - THE 1960 DONNER RIDGE FIRE IN CALIFORNIA SPOTTED 4 MILES BEYOND THE MAIN FIRE - THE 1967 SUNDANCE FIRE IN IDAHO SPOTTED 10 TO 12 MILES BEYOND THE MAIN FIRE FRONT DURING ITS PEAK RUN.	
1143	LET'S REVIEW THE FOUR METHODS OF HEAT TRANSFER A. RADIATION B. CONDUCTION C. CONVECTION D. SPOTTING	VU - GRAPH #1
	THESE ARE IMPORTANT BECAUSE THEY MAINTAIN AND SPREAD COMBUSTION.	
1145	QUESTIONS.	

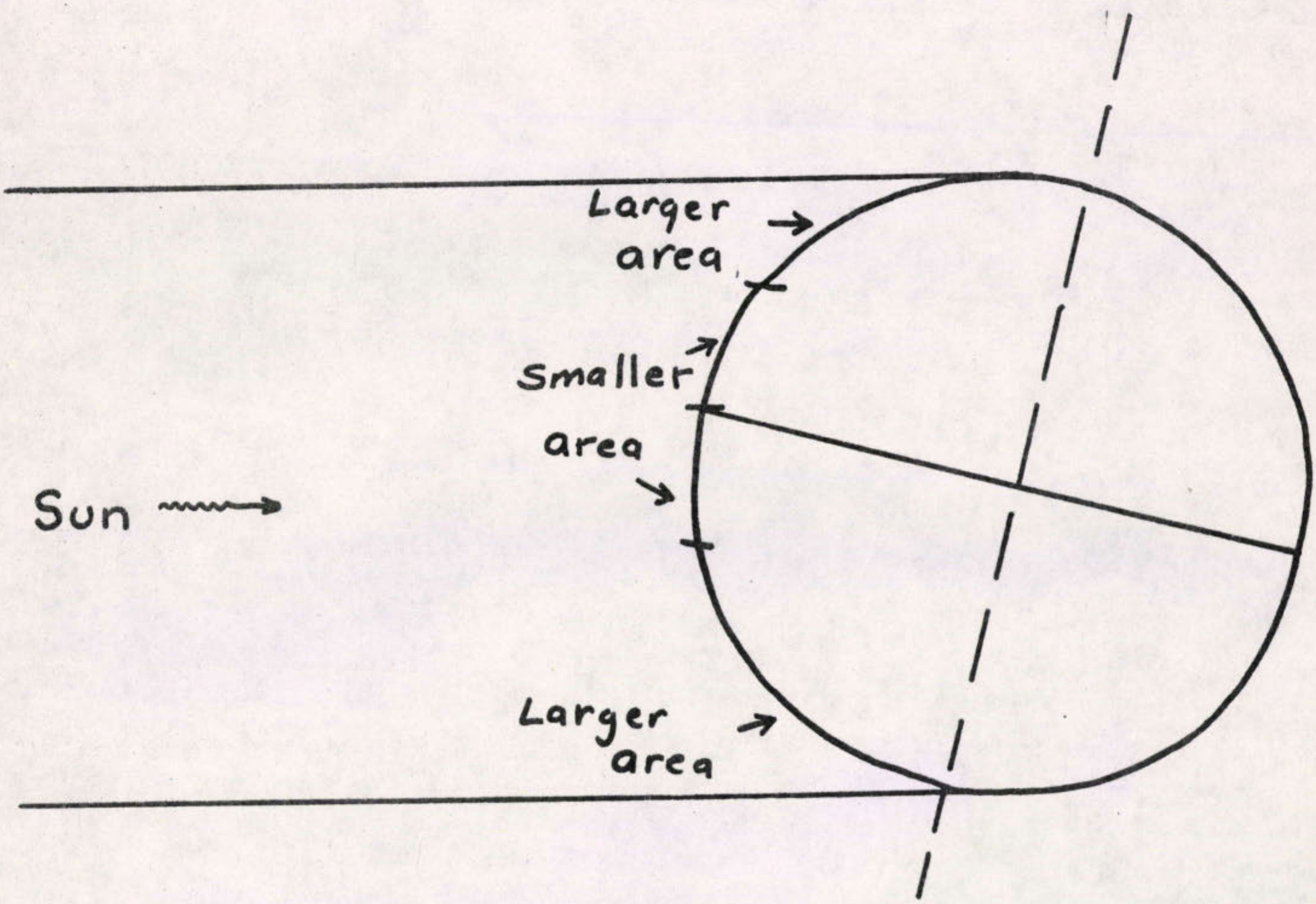

Mass Transport
Convection
Radiation
Conduction

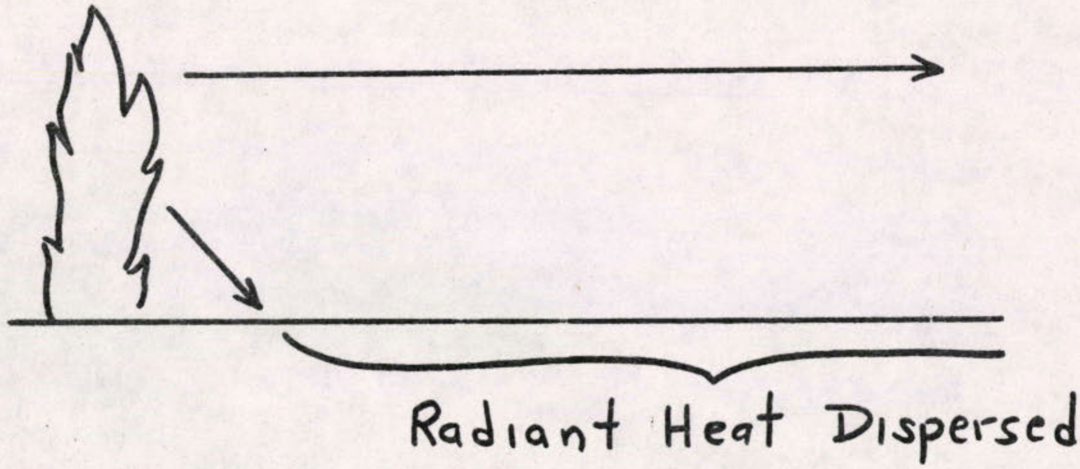


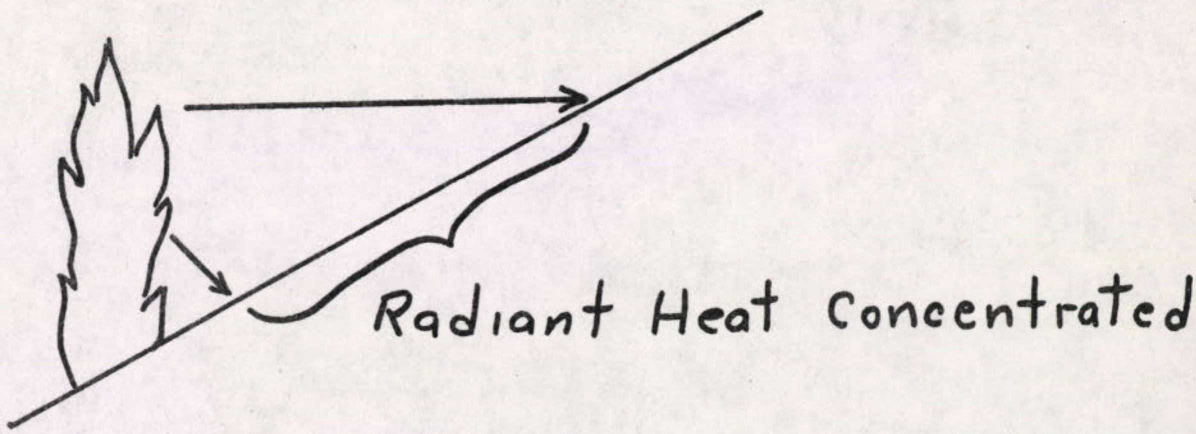
Radiant Heat



Absorption of Radiant Energy

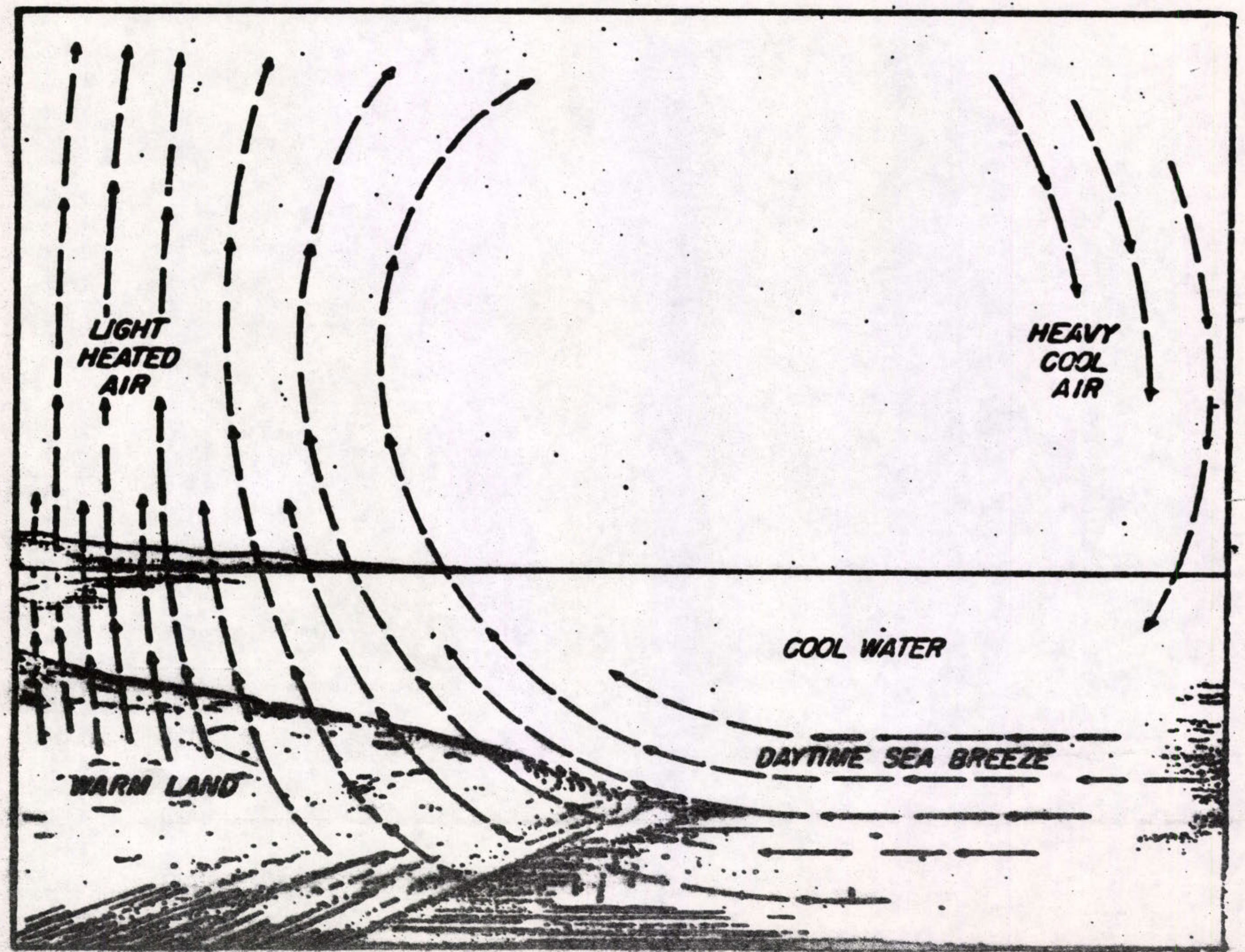

Larger area
Smaller area
Sun
Larger area

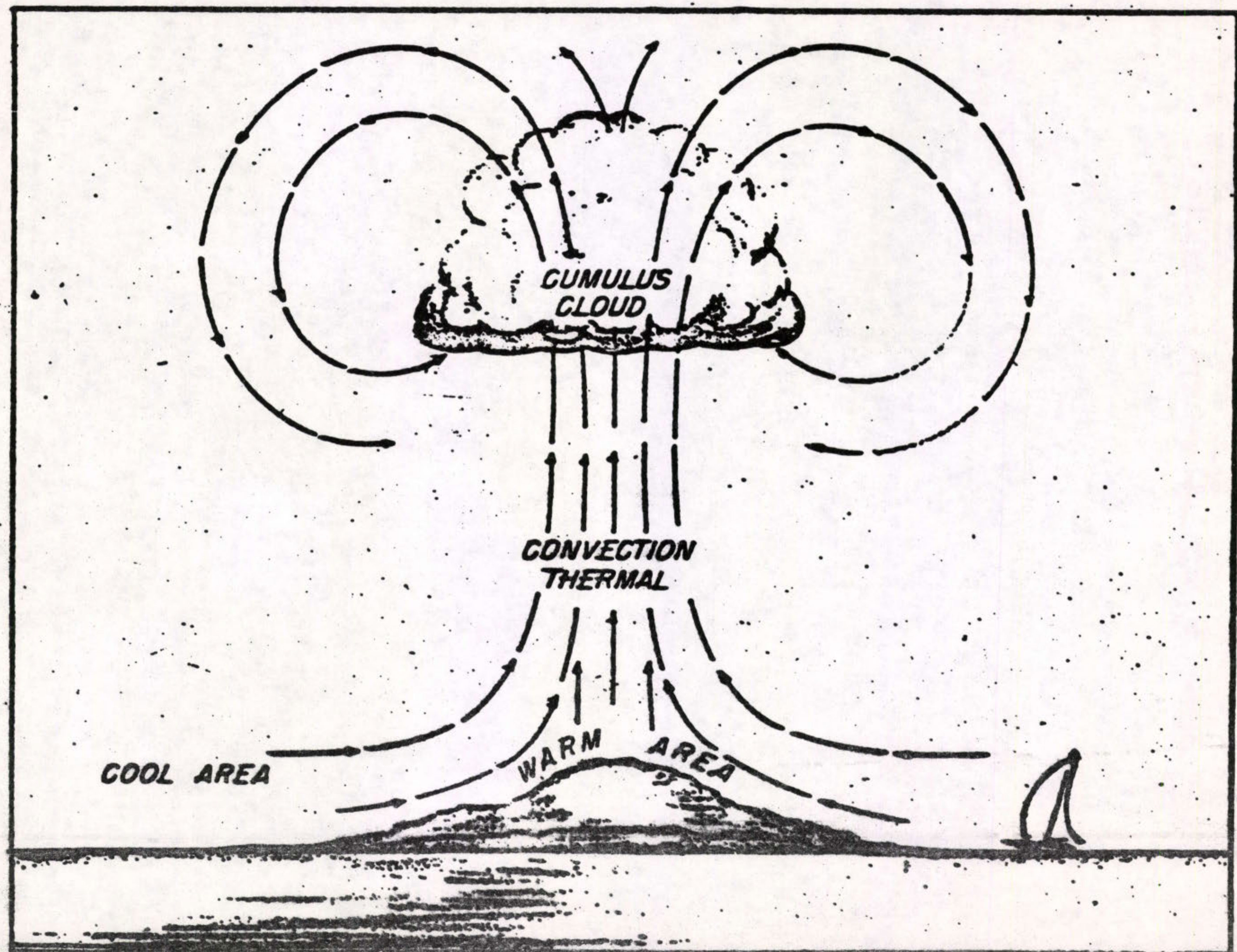

Radiant Heat Dispersed


Radiant Heat Concentrated

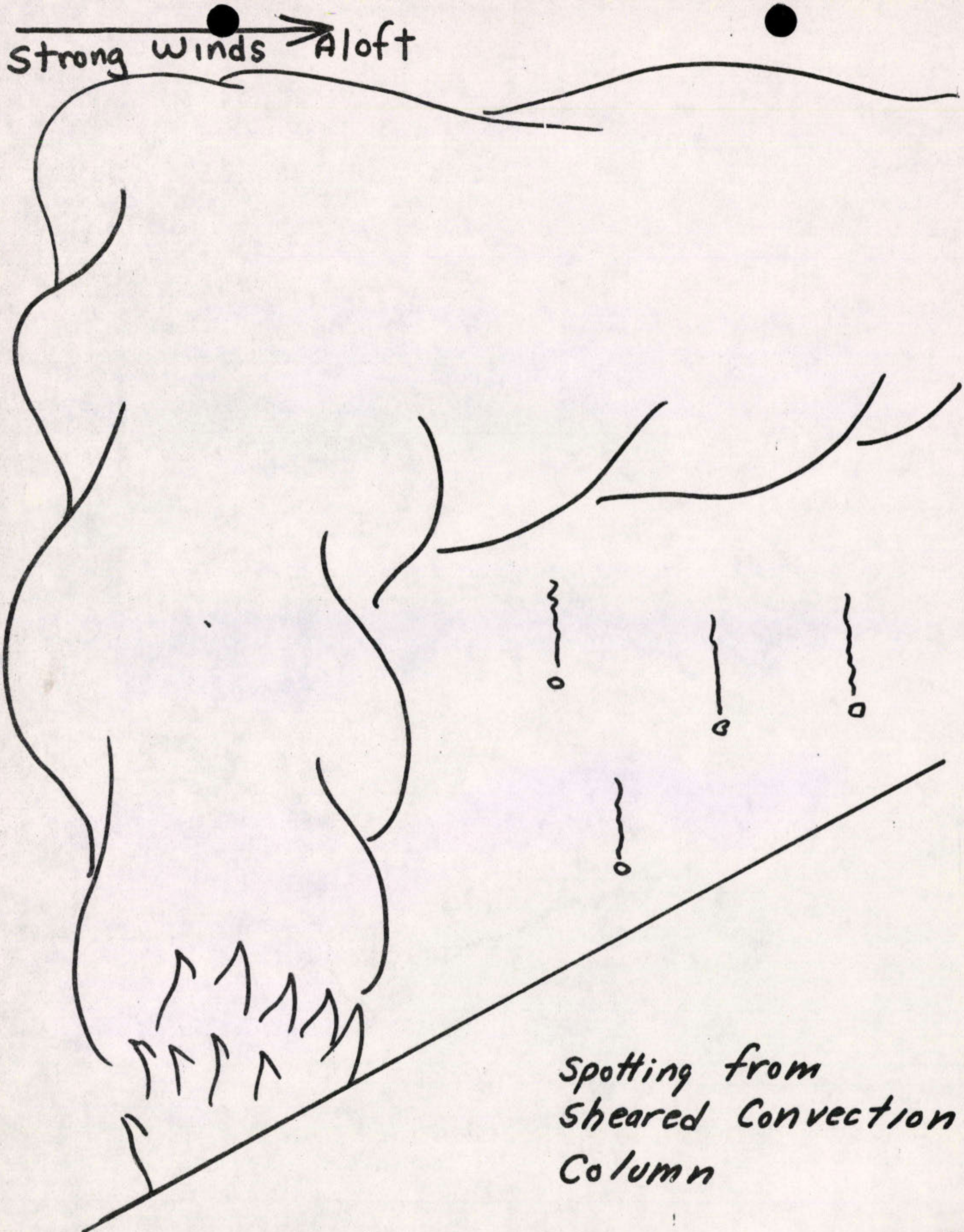
	Percent
Convective heat	61.7
Radiation	18.1
Conduction (into ground)	4.9
Heat value of Charcoal	1.0
Heat value of unburned gases	5.5
Heat unaccounted for	8.8
	100.0

Heat Balance in a Wood Fire


LIGHT HEATED AIR
HEAVY COOL AIR
COOL WATER
DAYTIME SEA BREEZE
WARM LAND



81



Spotting from Sheared Convection Column

INSTRUCTOR'S LESSON PLAN

SUBJECT: Fire Behavior
INSTRUCTOR Jim Sykes
TITLE OF LESSON: Forest Fire Energy Yield
FILE NO:
DATE: 3/16/71
LENGTH OF LESSON: 50 minutes
NO. ASSISTANTS:
METHOD OF INSTRUCTION: Lecture - discussion - demonstration
PLACE Rocky Mountain Station - Conference Room
TRAINING AIDS: See last page
NUMBER IN AUDIENCE: Approx. 70
OBJECTIVE: Learn to recognize fire, weather, topographic situations which can be expected to result in intense burning conditions so that henceforth they will take necessary action to prevent personnel entrapment

LESSON OUTLINE	KEY POINTS & AID CUES
INTRODUCTION	
"Forest Fire Energy Yield"	
I. New knowledge input may be low - emphasis on WHY of energy yield	Will use "Q" technique - stay awake if don't want rude awakening
A. Will quickly review energy storage	
B. Dwell at length on energy yield . . .	
1. From infinitesimally slow	
2. To unbelievably fast	
II. Two major categories of intense fires	
A. Straight-running, high-wind-driven	
1. Reasonably predictable behavior	
2. FBO - main job is assisting with fire strategy	
3. FSO - mainly routine fire safety	injurious & inconvenient hazards
B. Erratic fire behavior - with or without gradient wind	
1. Convection columns, fire whirls, highly unpredictable behavior	

TIME	LESSON OUTLINE	AIDS & CUES
	2. FBO - Personnel protection responsibility may exceed just strategy recommendations.	
	3. FSO - Has high killer potentials along with injurious and inconvenient potential	
	III. What can we do to prevent, alter, control, or avoid high energy yield.	
	A. Definite limitations - but some positive action	
	B. Responsibilities, however, not only remain - positively increased	Interesting demonstration
	C. First 5 Standard Orders have high energy yield situations as their genesis	Fire Chief story - "More hose"

TIME	LESSON OUTLINE	AIDS & CUES
	DEVELOPMENT	
	I. Review of energy	(Go Fast)
	A. Energy storage	
	1. Name of process(?) Photosynthesis	
	2. Energy Source(?) Sunshine-(heat)	
	3. Chemical Catalyst(?) Chlorophyll	
	4. Compounds(?) CO_2 & H_2O	
	5. Produce(?) Sugar, starch, cellulose, lignin	Seeds of its own eventual destruction - by oxidation
	6. By product(?) O_2	
	II. Non-fire energy yield or dissipation of heat	(Fast) Definite time
	A. Oxidation process called(?) decay	
	1. Cellulose + O_2 =(?) CO_2 + H_2O	
	2. Plus what(?) Energy	
	3. How much(?) Same it took to combine compounds in first place	
	B. Most energy, kinetic, chemical, mechanical eventually produces heat	
	1. Chemical energy - our problem(?) to maintain energy dissipation without heat accumulation	fire prevention

TIME	LESSON OUTLINE	AIDS & CUES
	2. No heat build-up in Forest normally without fire	green haystack-spontaneous combustion
	C. Similar to G-forces of vehicular impact	
	1. Given amount of kinetic energy	
	2. Stop in short time/space - unsurvivable "Gs"	
	3. Stop over longer time/space - survivable "Gs"	
	III. Fire energy yield - accumulation of heat-another form of oxidation - rapid this time. Several factors affect time available to release or dissipate given amount of stored energy.	Time/space can again affect survivability
	A. Fuel moisture - WHY(?)	
	1. Wood must be dried before its flammable vapors can be distilled - WHY(?) Heat going into steam production prior to completely dry.	
	2. B.T.U.s to heat 1 lb. water, 62° to 212° (?)	150 972 1122
	3. B.T.U.s to vaporize 1 lb. water(?)	
	4. B.T.U.s released in consumption of 1 lb. wood(?) 8,600	

TIME	LESSON OUTLINE	AIDS & CUES
	5. B.T.U.s utilized in steam production subtract from radiant energy available to propagate fire chain reaction.	13%
	6. Result - wet fuel will either or both -	
	a. Burn slower - more time to control	
	b. Burn cooler - allowing more direct attack - closer	Water injection of high performance aircraft engine
	B. Fuel arrangement (Volume/acre)	Yellowstone fire front '46
	1. Scattered, unpiled burning pieces do not irradiate each other as effectively - total energy yield largely dissipates with less mutual pre-heating	Radiation heat transfer largely
	a. This is why we separate to extinguish - with air or soil as non-flammable energy absorber	
	2. Unpiled but close proximity burning fuels -	
	a. Mutual pre-heating now HOW(?)	Radiation & conduction
	b. Same total energy yield - but in shorter time - so it gets hotter	

TIME	LESSON OUTLINE	AIDS & CUES
	3. Piled - vertical arrangement - "slope effect"	
	a. Even faster mutual pre-heating - WHY(?)	Radiation conduction & convection
	b. Same total energy yield - but in short time - high heat build-up	
	C. Fuel Size	
	1. Finer the fuel - faster it burns - WHY(?)	
	a. More surface to absorb heat energy	Demo - burn nail & "oo" steel wool
	b. More surface exposed to oxygen	
	2. Heavy fuel - same quantitative energy yield - (weight of wood products) but - if alone - released over longer time - hence less heat build-up	
	D. Fire intensity - combination of fuel moisture, arrangement and size . . . plus greater or lesser amounts of O_2	
	1. Wet, scattered, heavy fuel and still air - can't make it burn	Extremes
	2. Dry, piled, light fuel and windy - hard to stop if ignited	

TIME	LESSON OUTLINE	AIDS & CUES
	3. High intensity fires have significantly poorer combustion efficiency	Dark smoke carbon particle Red flame
	a. Actually burn cooler than better combusted fuel - for same volume of wood PRACTICAL EFFECT? Really none - plenty of fuel to provide more heat than can be handled directly - anyway.	Light smoke yellow flame
	4. Topography plays part - emphasizes or neutralizes gradient winds and heat transfer. High intensity fires can go: up, down or across the slopes.	
	5. Extreme intensity - even beyond free-burning convection column is CALLED(?) (Fire storm)	Fire whirl
	IV. Intense energy yield - because of extremely short burning time - near explosive energy yield - fire whirl or "thermally driven vortex"	Physically very similar to dust devil and tornado
	A. 3 apparently essential conditions and relative quiet air	Name the 3
	1. "Fluid sink" - "Heat sink" - brought about by convection column.	Draw or project - hor. & vert.

TIME	LESSON OUTLINE	AIDS & CUES
	a. Convection column - warm, light, rising air must be compensated by sinking cooler air in surrounding atmosphere.	Tiny "heat low" system
	2. "Generating Eddy" - also brought about by convection column and "heat sink"	Draw or project
	a. "Cell" of atmosphere in shape of cylinder, slowly turning around convection column	Like coil spring around overload shock absorber
	b. Revolves counter clockwise - probably due to "coriolis effect" - northern hemisphere.	Might be 50' to 1500' across
	c. Very slow movement at first but any circular movement at periphery of big "generating eddy" may still be quite a few radians - or fps.	Draw or project fps./1.5 = mph
	d. As more air is brought into system or "gen. eddy" - circulation thickens inward toward convection column - new air brought in at periphery	Draw or project
	e. Inner parcels of air still have same velocity (radians) but less horizontal distance and so develop vertical component - collectively induces spiraling effect.	Illustrate velocity vectors

TIME	LESSON OUTLINE	AIDS & CUES
	f. "Generating eddy" eventually contacts convection column - intense speeds of both revolution and updraft create near explosive burning conditions	
	3. 3rd essential - "Air friction" or drag to cause partial vacuum at ground otherwise it would have no anchor and would lift off and dissipate. Level ground helps this though contradicts "Fire Weather" somewhat.	Like air being pulled off an airplane wing causing a stall Sketch
	4. Fire vortex demonstration	Darken room
	B. Vortex energy yield many times greater than convection column (from larger model)	Small compared to 10-50 real whirl
	1. Vertical speed vector - 28 mph	
	2. Horizontal speed vector - 20 mph	
	3. R.P.M. - 2500 mph	40/sec. !
	4. Temperature - 2400^{o}	(Same fuel as demo.)
	5. Vortex - 1-50' diameter	
	6. Generating eddy - approx. - 20 x Vortex diameter	
	V. Practical application of fire whirl knowledge - not often seen - when they do occur - everyone must be alive to situation	FBO first!

TIME	LESSON OUTLINE	AIDS & CUES
	A. FBO - in particular - watch for spawning essentials	
	1. Unstable atmospherics - easier convection column establishment - "fluid or heat sink"	
	2. Generating eddy - harder to see - role of topography not completely understood. (Fire Weather book states leeside of ridge - protection from gradient winds.)	Flats to mtns. Sneaky point whirl - sketch
	3. "Dust devils" roundabout fire probably best tip off for fire whirl potential.	Emphasize
	B. Whirl apparent in formative stages	FBO warning
	1. Slurry <u>might</u> break up convection column, gen. eddy if small.	Plans - strategy Maximum effort if conditions favorable
	2. Ground applied water might break up convection column - hot spotting	
	3. Warn all affected personnel of potential intense erratic fire behavior: up, down, or across the slopes	Those in direct attack
	4. Prepare for long distance spotting and only indirect attack	

TIME	LESSON OUTLINE	AIDS & CUES
	SUMMARY	
	I. Well known factors of . . .	
	A. Fuel moisture	
	B. Fuel arrangement	
	C. Fuel size	Firefighting safe enuf in low & medium intensity fires
	D. Combine to affect fire intensity - wind also factor - to erratic behavior	
	II. Less known factors cause most of our fire fatalities to ground personnel	High intensity fires create killer hazards extremely fast
	A. Don't/can't comprehend burning intensity - speed or energy (heat) yield	FBO that misses indicators of fire whirl jeopardizes lives - I know I missed once & we weren't sure for a while we hadn't lost a crew in the whirl!
	B. Mere man no real match for fire storm when he "paints himself into a corner"	
	Ref: "The Modeling of Fire Whirlwinds" by Geo. M. Byram and Robert E. Martin - December 1970 issue of Forest Science	

TIME	LESSON OUTLINE	AIDS & CUES
	Training aids	
	Matches	
	"oo" steel wool	
	tongs	
	whirl chamber	
	2 lids	
	steel plate	
	alcohol	
	2 easels with pads	
	black, green, red, orange, blue inks	
	small table	
	pointer	
	fire colors	

INSTRUCTOR'S LESSON PLAN

COURSE: Intermediate Fire Behavior | PLACE: Fort Collins, Colorado
DATE: March 16-18, 1971
TITLE OF LESSON: Basic Weather | INSTRUCTOR: G. R. Miller
LENGTH OF LESSON: Two hours
TRAINING AIDS: Overhead projector, slides and easel.
OBJECTIVES: (1) To define basic weather conditions and discuss same, (2) Clarify your current knowledge of Meteorology, (3) To understand the effects of various weather elements, and (4) To stimulate improved teamwork between you and the Fire Weather Meteorologist.

TIME	Lesson Plan	Key point or aid
	Introduction	
1400	To most people, weather conditions often appear as a bewildering hodgepodge of changing events that have no systematic organization. Weather IS complicated. Several processes are in action simultaneously. But it is not so complicated that we can not understand the primary factors that cause basic weather events.	
	You are not expected to become a weather forecaster. I am not a forester, but if each of us knows just a little about the problems and ideas concerning the other, we will both be in a much better position to combat fire and extreme fire conditions. If you have the attitude, "I am not a meteorologist, therefore I can't (or won't) understand weather," forget it. It involves you just as Forestry involves me.	
	Composition of Air	
1405	Air is a mixture of several gases, mostly nitrogen (78%), oxygen (21%) and other gases (1%). The gases are not united chemically. The molecules of each gas merely share the same space.	View graph #1
	Water vapor is the name for the gaseous state of liquid water. It is invisible, like most other gases. Water vapor is ALWAYS part of the mixture of gases in air, as found in nature. What is important is the amount of water vapor. It is variable because of the frequent change of state of water in weather processes. Water vapor readily condenses into liquid water, or freezes into solid ice.	AMOUNT of water vapor is important. Readily condenses or freezes.
	In spite of impressive evidence of moisture in the air, such as clouds, rain, snow, etc., water vapor seldom occupies more than 4% of any air space, even if the relative humidity is 100%. Its average would probably be less than 1%. Water vapor is the gas that has the most pronounced effect on the weather.	Average amount of water vapor is generally less than 4%.

Time	Lesson Plan	Key point or aid
	Concepts of Gaseous Pressure & Density Pressure is defined as force (or push) per unit area. Pressure is the collective impacts of molecules. Imagine a room filled with flying ping-pong balls (molecules). The more balls (greater density) the more pressure. Also, the faster they are moving (higher temperature) the more pressure. As you can see, pressure depends partly on the density of a gas and partly on the temperature. Pressure and density are not the same thing. The density of a gas depends on the number of molecules in a given space, and the weight of these molecules.	Pressure depends on the density of a gas and the temperature.
1410	Structure of the Atmosphere - Pressure The atmosphere is held against the earth by the force of gravity. Imagine the atmosphere as a series of layers, one on top of the other. Each layer of air is compressed by the weight of the layers above. The layer next to the ground is compressed the most. Atmospheric pressure decreases with elevation, rapidly at first, then more slowly. For instance at sea level the pressure is 14.7 lbs./sq.inch or 1,013.2 millibars or 29.92 inches of mercury. At 18,000 feet, 7.34 lbs./sq.inch or 506.0 millibars or 14.94 inches of mercury. At 50,000 ft it is 1.68 lbs./sq.inch or 116.0 millibars or 3.42 inches of mercury.	Gravity holds air to earth. Pressure decreases with increasing elevation. View graph #2
	Structure of the Atmosphere - Temperature The distribution of temperature with altitude is highly variable, but we can divide the atmosphere into number of real layers.	View graph #3
1415	The layer from sea level up to about 36,000 feet is called the troposphere. It is characterized by decreasing temperature with altitude, although relatively shallow layers often show "inversions" or an increase in temperature with an increase in elevation. Nearly all of the water vapor in the atmosphere is contained in this lower layer. Also there is considerable up and down motion of the air called turbulence.	Lowest layer is called troposphere.
	Between 7 miles and around 50 miles we find the stratosphere. It is sometimes divided into a lower and an upper part. The boundary between the lower stratosphere and the troposphere is called the tropopause.	View graph #4 Tropopause is the boundary between stratosphere and troposphere.
	Lately meteorologists have detected areas of what	

Time	Lesson Plan	Key point or aid
	they term are "stratospheric warming". They are only very little understood and their effect on the weather is only speculation now.	
	The height of the tropopause varies around the globe. It is lowest at the poles, where it's also the warmest and it is higher at the equator where it is also the coldest.	View graph #5
1420	<u>Air Motion</u> Air in motion, or wind, is involved in nearly every fire control problem. There are many kinds of wind. Some winds are local, and exist for only short periods of time. Some winds create broad scale patterns over large areas and persist for much longer periods of time.	
	Everyone is acquainted with weather maps which may show isobars, centers of high and low pressure and storm fronts. The information comes from weather observations made simultaneously in many places.	View graph #6
	Broad scale air motion is revealed by the isobars on a weather map. An isobar is a line of constant pressure in the same sense that a contour line on a topographic map is a line of constant elevation. The wind blows along or slightly across the isobars Weather maps are evidence of the organized nature of air motion over the earth.	Isobar is a line of constant pressure.
	Air motion is caused by several factors: 1. Uneven heating and cooling 2. Gravity 3. Rotation of the earth 4. Pressure gradients We will discuss each separately.	
1425	<u>Uneven heating</u> or cooling results from the spherical shape of the earth, the seasonal inclination of the sun, the rotation of the earth, the variety of surfaces on the earth and the aspect or slope of the ground.	
	Difference of temperature, caused by uneven heating or cooling, is the initial cause of all air motion. The short-lived differences in temperature produce wind types which are short-lived, such as most local winds. Persistent or broad scale differences in temperature produce wind types which are persistent or broad scale. Such are the major wind circulation areas over the earth.	Use easel

Time	Lesson Plan	Key point or aid
	In equatorial regions the earth's surface receives more solar energy from the sun than it radiates back to space, and therefore acts as a heat source for the air in these regions. In polar regions the earth's surface radiates more energy into space than it receives from the sun. Since equatorial regions do not get hotter and hotter and polar regions do not get colder and colder, there must be some net transport of heat energy from equatorial to polar regions.	Equator is a source of heat. Polar regions lose heat.
1430	Near the equator the warm air rises to near the tropopause, reaches a level of same air density and then spreads out and flows both north and south. As it moves towards the poles it cools by radiation and sinks as its density increases. In the polar regions it descends and begins to move toward the equator.	Air rises near the equator and sinks near the poles.
	Meteorologists know that the process is much more complicated than this. In fact there are three main wind belts between the equator and the poles. These are the trade winds, the prevailing westerlies and the polar easterlies. In between the trade winds and the westerlies are the "horse" latitudes and in between the prevailing westerlies and the polar easterlies is the polar front.	Three main wind belts: Trade winds, prevailing westerlies and polar easterlies.
1435	<u>Gravity</u> acts to arrange fluids in layers with the most dense on the bottom and the least dense on the top. The unevenly heated atmosphere is set in motion by the force of gravity to distribute the cold, dense air at the bottom and the warm, less dense air at the top.	
	<u>Rotation of the earth</u> hinders the normal north and south flow of air. In the northern hemisphere a current of air is turned to the right as it moves forward. This "turning tendency" is called the Coriolis force. It acts similarly on wind from any direction.	In the northern hemisphere moving air is deflected to the right.
	Rotation is a type of motion which involves turning only. The ground is rotating counterclockwise in the northern hemisphere. Because of inertia, wind tends to move in a true straight line. Because we describe air motion with respect to the ground, moving air appears to turn clockwise, simply because the ground is turning counterclockwise.	View graph # 7

Time	Lesson Plan	Key point or aid
	A pressure gradient is portrayed by isobars. Isobars outline areas of relatively high or low pressure and show the rate of change in pressure from one location to another. The pressure gradient is oriented from high pressure to low pressure, at right angles to the isobars. The concept is comparable to downhill slope on a topographic map.	Use easel
	A pressure gradient tends to move air for an obvious reason. How it develops in the first place is not so obvious. The development of pressure gradients accompanies the formation of a low pressure area.	
1440	Humidity and its Measurement Humidity refers to the water vapor content of the atmosphere. The primary source of water vapor for the atmosphere is the ocean. The capacity of the air to hold moisture is directly proportional to its temperature. The capacity of the air to hold water in vapor form is approximately doubled for every 20° F increase in temperature. When air contains its maximum amount of water vapor, it is saturated. When it contains less than its maximum it is unsaturated.	Humidity refers to amount of water vapor in the air. View graph #8 Saturated air has a humidity of 100%.
1445	Relative Humidity is a ratio of the amount of water vapor in the air compared to the amount it would have if it were saturated. Let us assume that we have a closed vessel with dry air. Somewhat fictitious since we earlier said there is no such "animal" as completely dry air. But for this purpose, let's assume this. If we set a pan of water in the bottom of the vessel, evaporation begins immediately. After a period of time the air above the water might become one-quarter saturated, and we would say that the relative humidity was 25%. In other words the relative humidity is the quantity of water vapor expressed as a percent of the quantity required for saturation at that temperature. As evaporation continues in the closed vessel, the relative humidity rises until it becomes 100%. Further evaporation will not increase the relative humidity. The excess water vapor condenses into water droplets.	Relative humidity is a ratio of amount present to amount possible.
	The dewpoint temperature is the temperature to which air must be cooled in order for saturation	

Time	Lesson Plan	Key point or aid
	to occur. Let us imagine air of 60° F and 50% relative humidity. If this air is cooled and the actual moisture content remains the same, the air would be able to hold less moisture so that the relative humidity would increase. If this process would continue, then saturation would be reached. This is the dewpoint temperature. If the air is cooled further, both temperature and dewpoint would decrease equally, condensation would take place, and the air would still remain saturated.	View graph #9
1450 -	Fluctuation of relative humidity due to changes in temperature should not leave one with the impression that the water vapor content of the atmosphere also fluctuates in the same manner. Changes in water vapor content may be brought about by the advection of more or less moist masses of air. Evaporation from water surfaces adds to the moisture, whereas condensation and precipitation remove moisture from the air. Vertical currents can likewise cause a redistribution of the moisture content in various layers of the atmosphere.	
	The <u>psychrometer</u> consists of a wet bulb and a dry bulb thermometer mounted side by side. The wet bulb has a moist wick around its bulb. The psychrometer is ventilated and if the air is not saturated, water will evaporate from the wicking. This will cool the wet bulb and lower the wet bulb temperature. The wet bulb temperature is defined as the temperature that air assumes by the evaporation of water into it. Only in isolated cases, other than at saturation, is it the same as the dewpoint temperature. The difference between the dry bulb temperature and the wet bulb temperature	Wet bulb temperature
1455	is called the wet bulb depression.	
	The drier the air the faster evaporation will occur from the moist wick. On the other hand, if the relative humidity of the air is 100%, then no evaporation will occur. Then, the dry blub, wet bulb, and dewpoint temperatures are identical. Psychrometric tables have been prepared for use with the psychrometer to determine the relative humidity from the wet and dry bulb readings.	
	Other instruments such as a hygrograph, which measures humidity and hygrothermograph, which measures both temperature and humidity are used.	

Time	Lesson Plan	Key point or aid
1520	<u>Airmasses</u> An airmass is defined as a widespread body of air that is approximately homogeneous in its horizontal extent, particularly with respect to temperature and moisture. In addition the variation of temperature and moisture in the vertical is approximately the same in all parts of the airmass.	Airmass: body of air with same properties horizontally and vertically.
	The surface of the earth has a strong effect on the atmosphere in the processes of warming and cooling, or wetting and drying. However, these processes tend to proceed rather slowly. A source region is an extensive area of the earth's surface over which bodies of air remain for a sufficient period of time to acquire the characteristic temperature and moisture properties imparted by that surface. Once these properties are obtained, they are retained for some length of time. Portions of the atmosphere become identifiable as a distinct airmass.	View graph # 10 Source regions are primarily oceans, polar regions and continental regions.
1530	Airmasses are classified first according to the prevailing temperature in their source regions: Tropical (T) Polar (P) Arctic or Antarctic (A). To describe the distribution of moisture, the source regions are distinguished as: Continental (c) Maritime (m). The most common airmasses in North America are mT, mP, cP, and cA. Continental tropical, cT, and maritime arctic, mA, are less common.	Air masses classified according to source regions.
	A special designation is sometimes added to assist in describing the turbulence or lack of turbulence in the surface layer of an airmass moving across a new area after leaving its source region. If air moves over a relatively cold surface, tending to chill the lowest layer, the subscript "w" is added. If air moves over a relatively warm surface, tending to heat the lowest layer, the subscript "k" is added. This means that the air is warmer (w) or	View graph #11
1535	colder (k) than the surface over which it is moving	
	For example, mT air moving up the Mississippi Valley in winter becomes mTw and cA air moving southward down the Mississippi Valley in Winter becomes cAk.	
	An airmass assumes the character of its enviroment either by stagnating over a particular area or by moving for a long period of time over a large area	

Time | Lesson Plan | Key point or aid

of uniform conditions such as an ocean. The time required to reach typical identity is from 2 to 10 days. As it moves to another area beyond its source region, the airmass undergoes modification and changes gradually into another airmass. New conditions will change the temperature and moisture, not only in the lower layers, but also throughout the vertical extent of the airmass.

About 2 to 10 days is required for an air mass to reach homogeneity. Airmasses are modified as they move from their source region.

In the day to day work of following airmasses, which move over the face of the earth, any system of labels becomes rather complex. Maritime polar air becomes drier over land and changes into continental polar air. Continental polar air moves over a warm ocean and becomes maritime polar air.

In recent years upper air soundings have been made at more and more locations and at 12-hour intervals. Accurate numerical values are obtained for temperature, moisture and stability at many points within each airmass. This extensive supply of specific data renders less necessary the descriptive labels for the airmass. Graphs which describe the individual characteristics of the atmosphere over a station are prepared on adiabatic charts.

1545 <u>Fronts</u>

The boundary zone between airmasses of different characteristics is call a front. If the contrasts are small or the transition zone rather wide, the front is weak or diffuse and is associated with little or no weather activity. If the contrasts are large or the transition zone rather narrow, the front is strong and is usually associated with considerable weather activity. Since airmasses display fairly uniform characteristics inside their boundaries, it follows that fronts must be zones where transition is concentrated. Although several air mass characteristics change across a front, the basic structure of the front depends on the transition in temperature. If the new airmass arriving at a location is colder than the previous airmass, the transition zone is called a cold front. If the new airmass is warmer than the previous one, the transition zone is called a warm front.

A front is the boundary between two different air masses

View graph #12

Warm front and cold front defined.

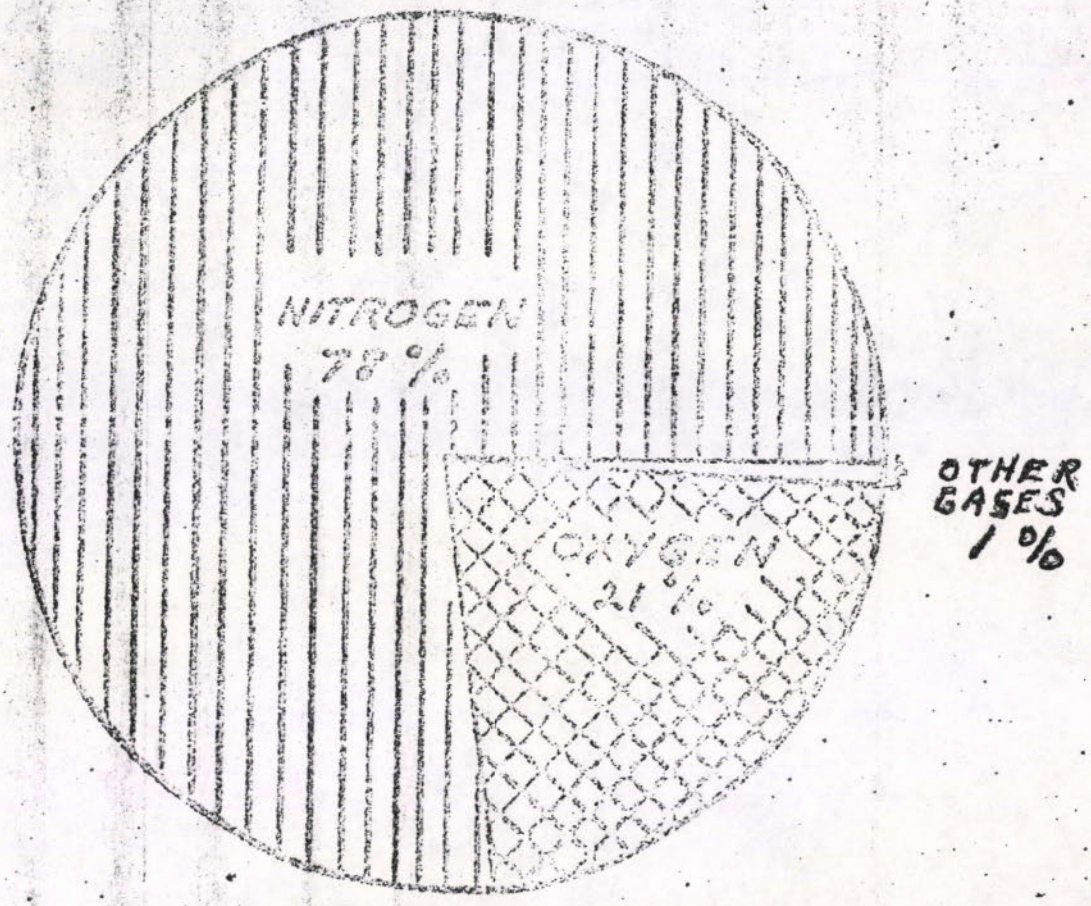
Fronts are distinct only in the lower portions of the atmosphere. They are formed in what meteorologists call troughs of low pressure. In the North-

View graph #13

Time	Lesson Plan	Key point or aid
	ern Hemisphere winds shift in a clockwise direction with the passage of a front. There are some variations with this rule, however. Along the west coast of the United States winds will sometimes shift in a counterclockwise direction with the passage of a "sea breeze" front. Also, when winds are light, they may appear to shift in a counterclockwise direction with the passage of a front due to eddies or the weakness of the front.	In general, winds will shift in a clockwise direction with the passage of a front.
1600	The vertical structure of fronts is helpful in understanding weather phenomena associated with them. A cold front is an advancing wedge of colder air. The warm air is pushed back or is forced upward. Gravity is trying to arrange the cold air on the bottom layer and the warm air on the top layer. The position of the cold front on the sea level map is the intersection of the sloping cold frontal surface with the earth's surface. As the cold air moves, so must the cold front move. A warm front surface similarly slopes upward over the colder air, but as the warm air advances, it is free to overrun the colder air. The colder air cannot be forced upwards, and it is pushed backward less easily. Hence, cold fronts move more rapidly than warm fronts, usually.	Cold fronts push warm air ahead of them aloft. Warmer air as it advances is forced aloft over the cold air.
1615	"Dry" cold fronts often cause very severe fire weather. They are termed "dry" because of the lack of or sparsity of moisture associated with them. There is usually a definite wind shift as they pass. They have been the cause of a number of fire "blow-ups". Cold fronts tend to be drier farther away from the low-pressure center with which they are associated. Their mention in weather forecasts should not be taken lightly. They are dangerous.	Dry cold fronts
	We have mentioned that a cold front generally moves faster than a warm front. In most cases it will eventually "catch up" with the warm front. The result is an occluded front. Satellite photos are beginning to reveal some interesting things about fronts. One of these is that the occlusion process may be instantaneous as a surface "wave" is overtaken by a trough of low pressure aloft.	Occluded fronts View graph #14
	In general the faster a front is moving, the stronger it will be. Fire control people should be more concerned with cold fronts than warm fronts.	

Time	Lesson Plan	Key point or aid
	You have just been given some of the basics of weather. There are only a few "hard, fast" rules that can be applied. Weather has macro-variations on the broad scale or large scale to micro-variations on the very small scale.	
1630	Some excellent textbooks have been written on weather, particularly concerning fire weather. "AGRICULTURE HANDBOOK 360, Fire Weather, is an exceptionally good one. Another fine one is AVIATION WEATHER, printed jointly by the Federal Aviation Agency and the Department of Commerce. If the answer can not be found here for your question, your fire weather meteorologist should be consulted. If he can not help you -- pray!!	Useful textbooks

#1

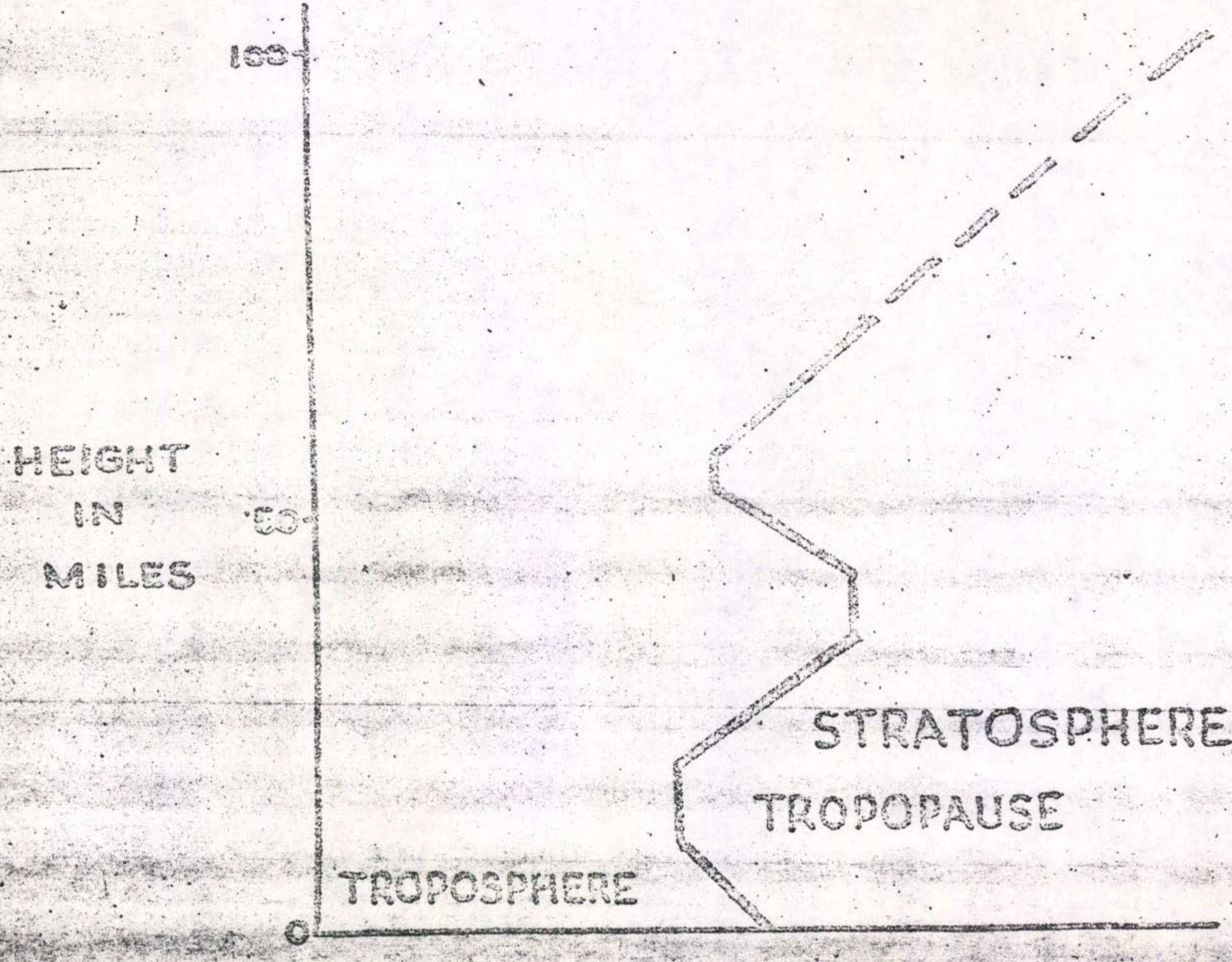


PERCENTAGE OF ATMOSPHERIC GASES BY VOLUME (DRY AIR)

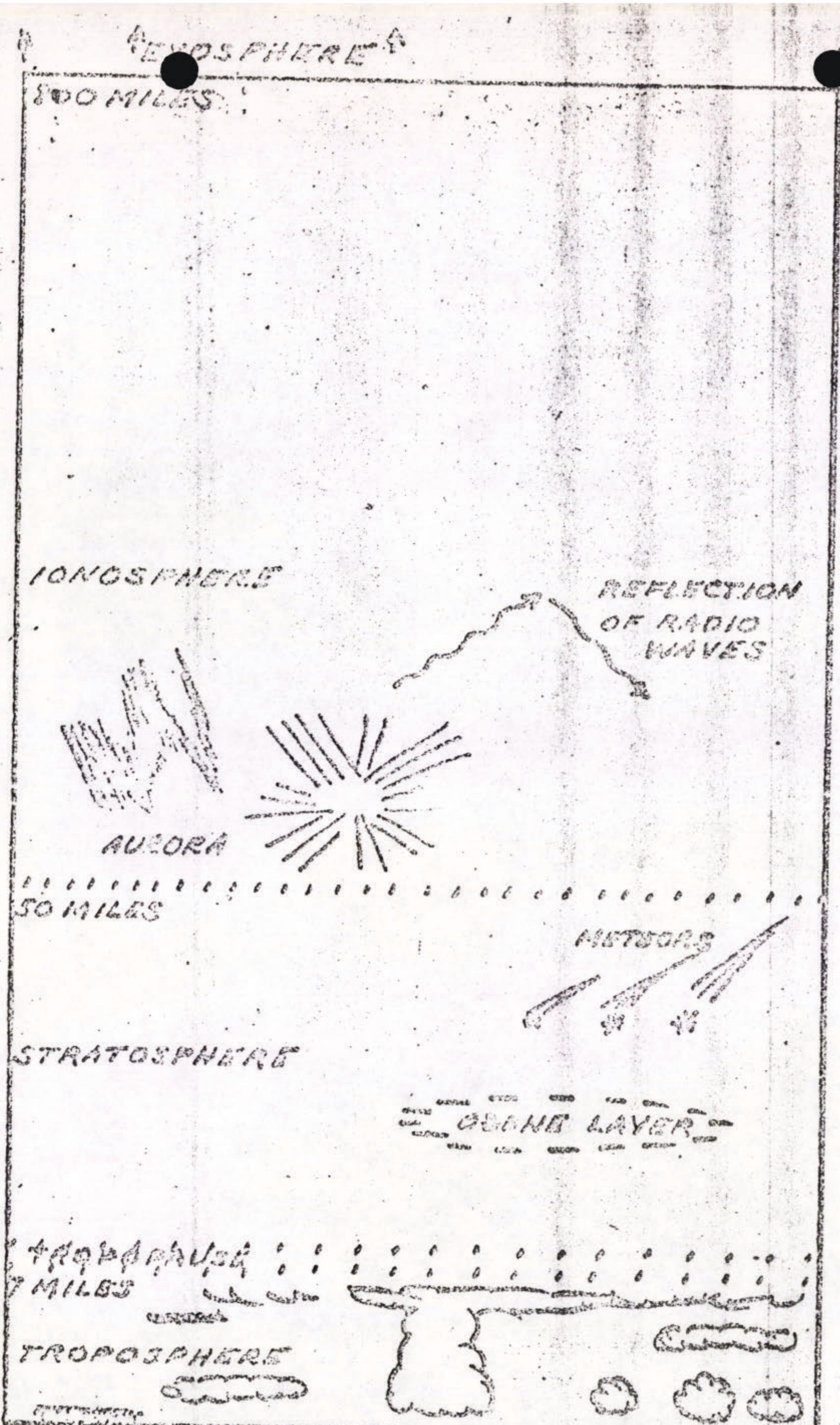
Atmospheric Pressure vs. Altitude above Sea Level

	Pressure		
Height (feet)	lbs/in²	millibars	inches Hg.
100,000	0.15	10.5	0.31
50,000	1.68	116.0	3.42
18,000	7.34	506.0	14.94
10,000	10.11	696.8	20.58
sea level	14.70	1013.2	29.92

#3

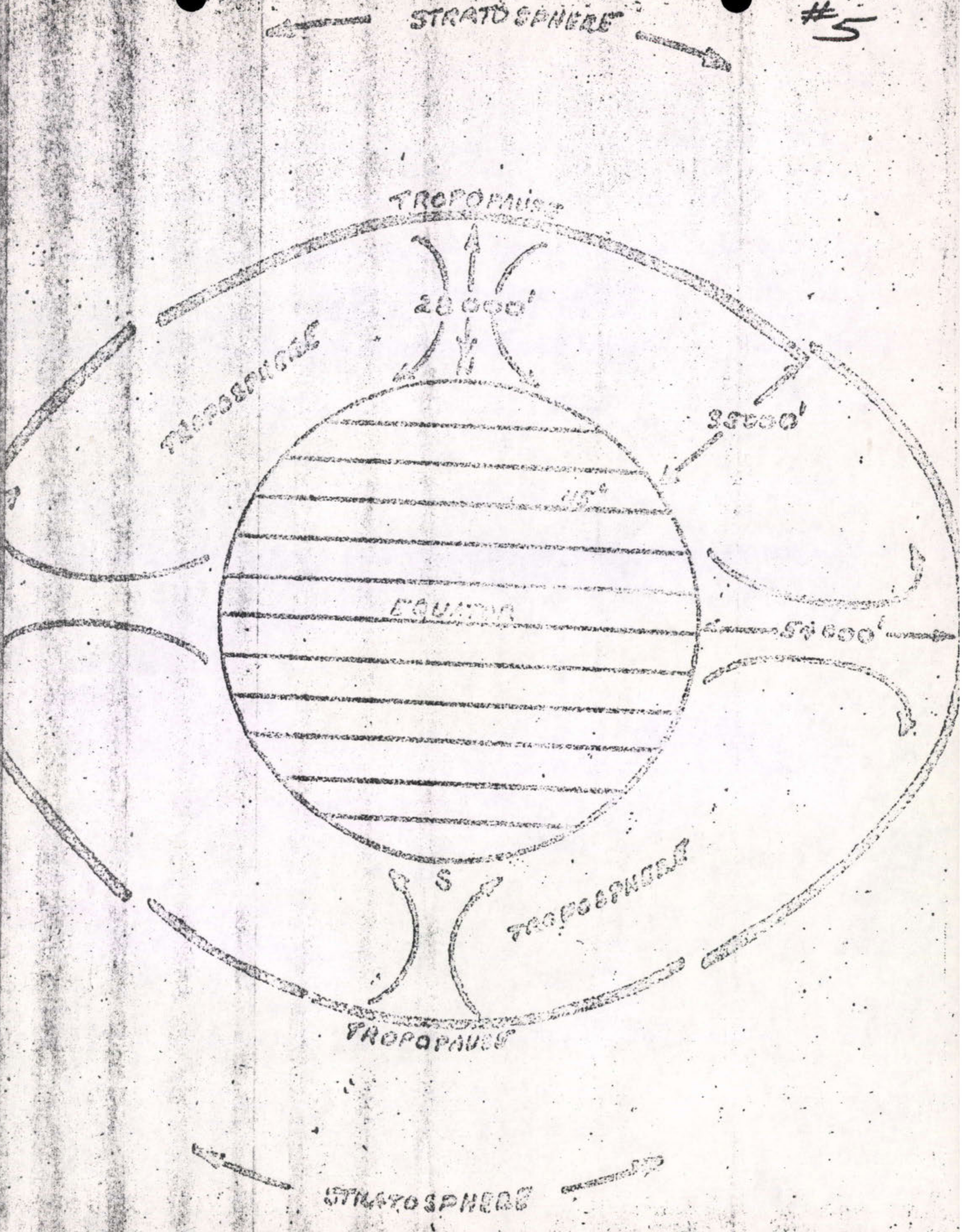

100
50
0
HEIGHT
IN
MILES
STRATOSPHERE
TROPOPAUSE
TROPOSPHERE

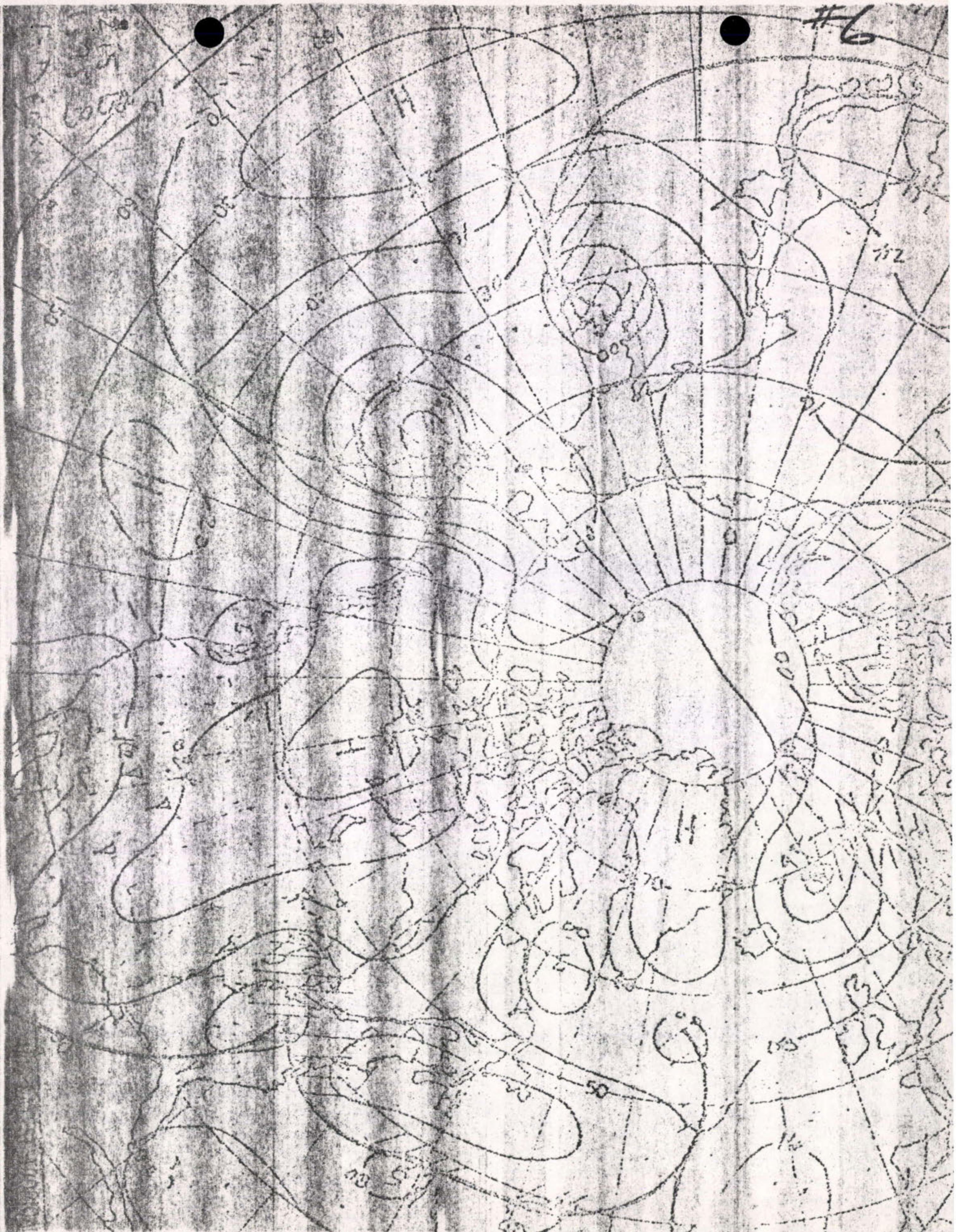
#4



STRUCTURE OF THE ATMOSPHERE

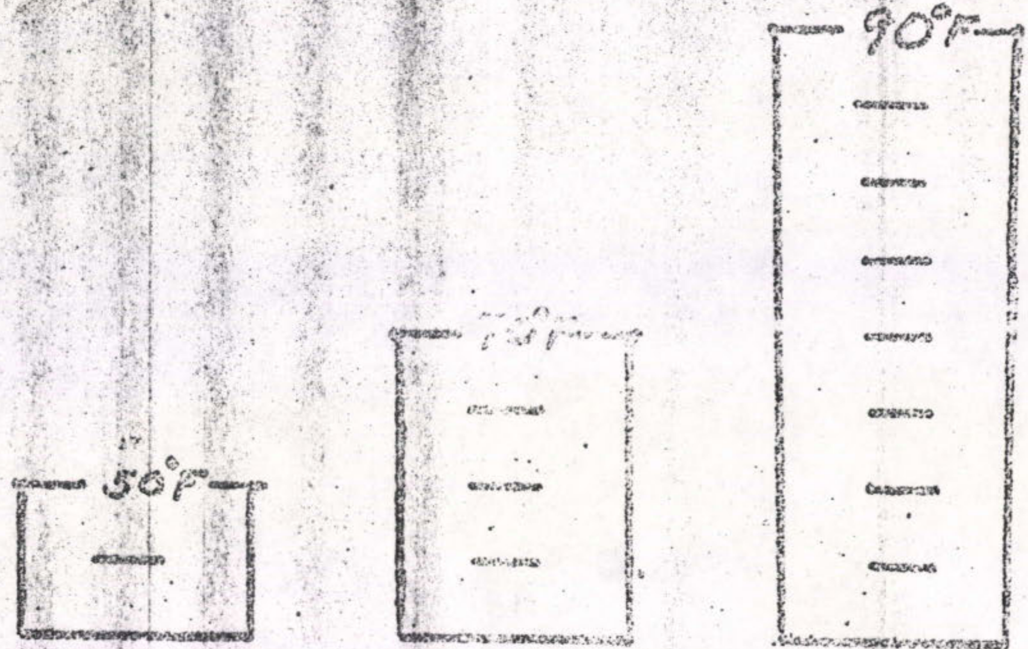
#5


STRATOSPHERE
TROPOPAUSE
28 000'
TROPOSPHERE
35000'
45°
EQUATOR
55 000'
S
TROPOSPHERE
TROPOPAUSE
STRATOSPHERE


#6

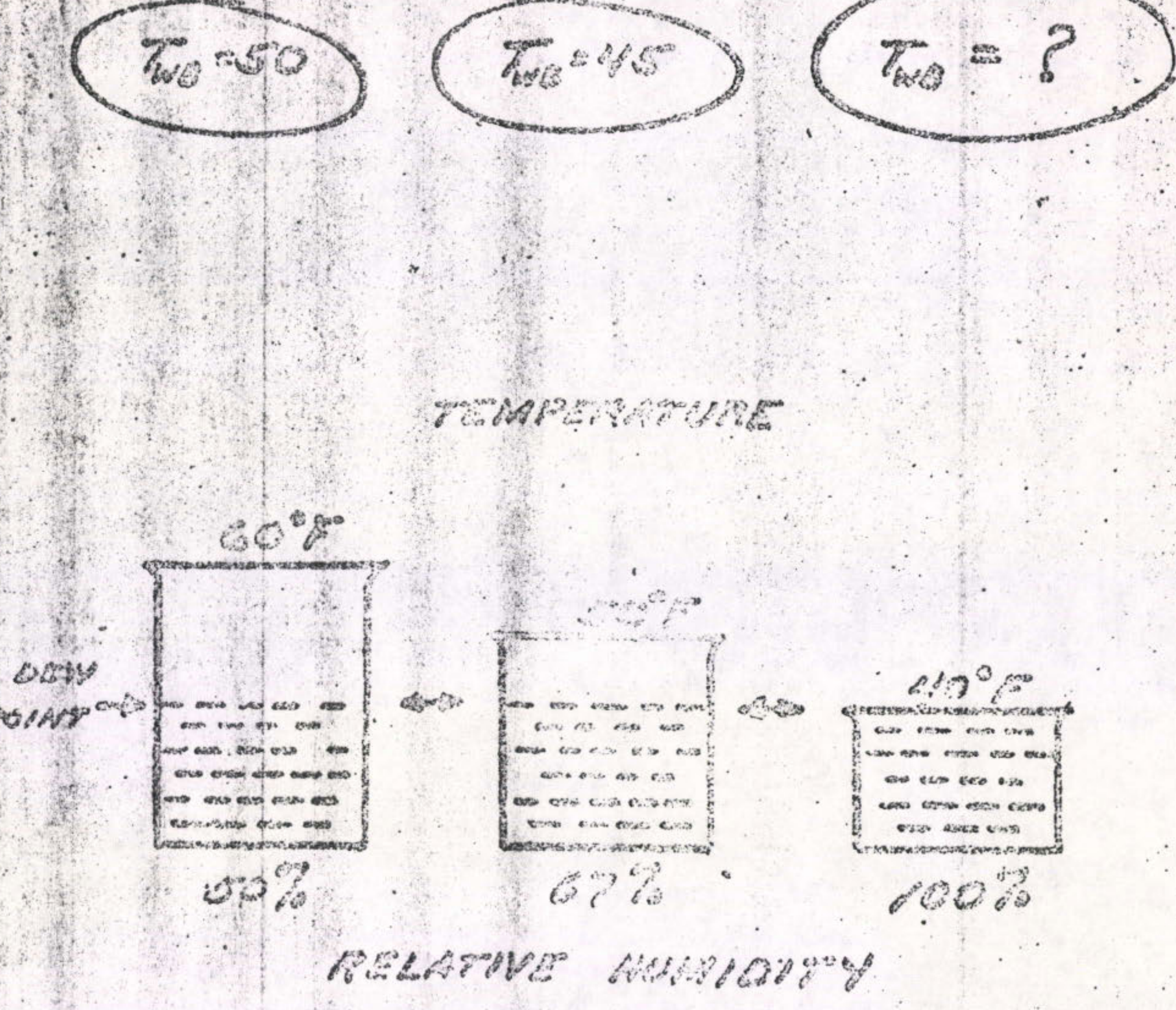
#7 This one is to be blank

#8



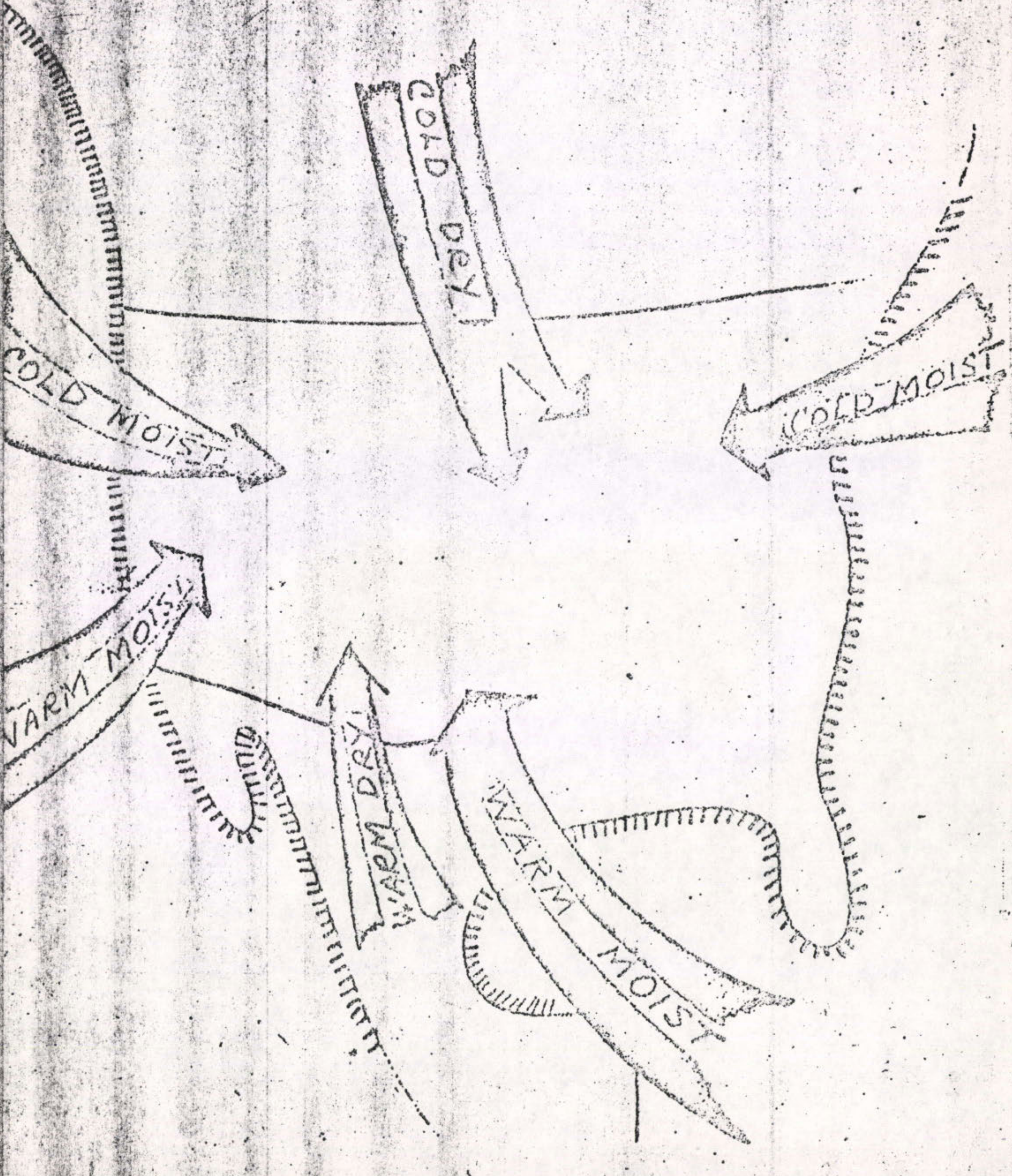
RELATIONSHIP BETWEEN TEMPERATURE AND POSSIBLE WATER VAPOR CONTENT OF THE AIR

#9



EXAMPLE OF RELATIONSHIP BETWEEN TEMPERATURE, DEWPOINT, AND RELATIVE HUMIDITY

#10


COLD DRY
COLD MOIST
COLD MOIST
WARM MOIST
WARM DRY
WARM MOIST

CLASSIFICATION OF AIR MASS

1. ACCORDING TO SOURCE REGION

2. WHETHER CONTINENTAL OR MARITIME

3. WHETHER AIR MASS IS COLDER OR WARMER THAN SURFACE OVER WHICH IT PASSES (STABILITY)

CODE:

A - ARCTIC

P - POLAR

T - TROPICAL

C - CONTINENTAL

M - MARITIME

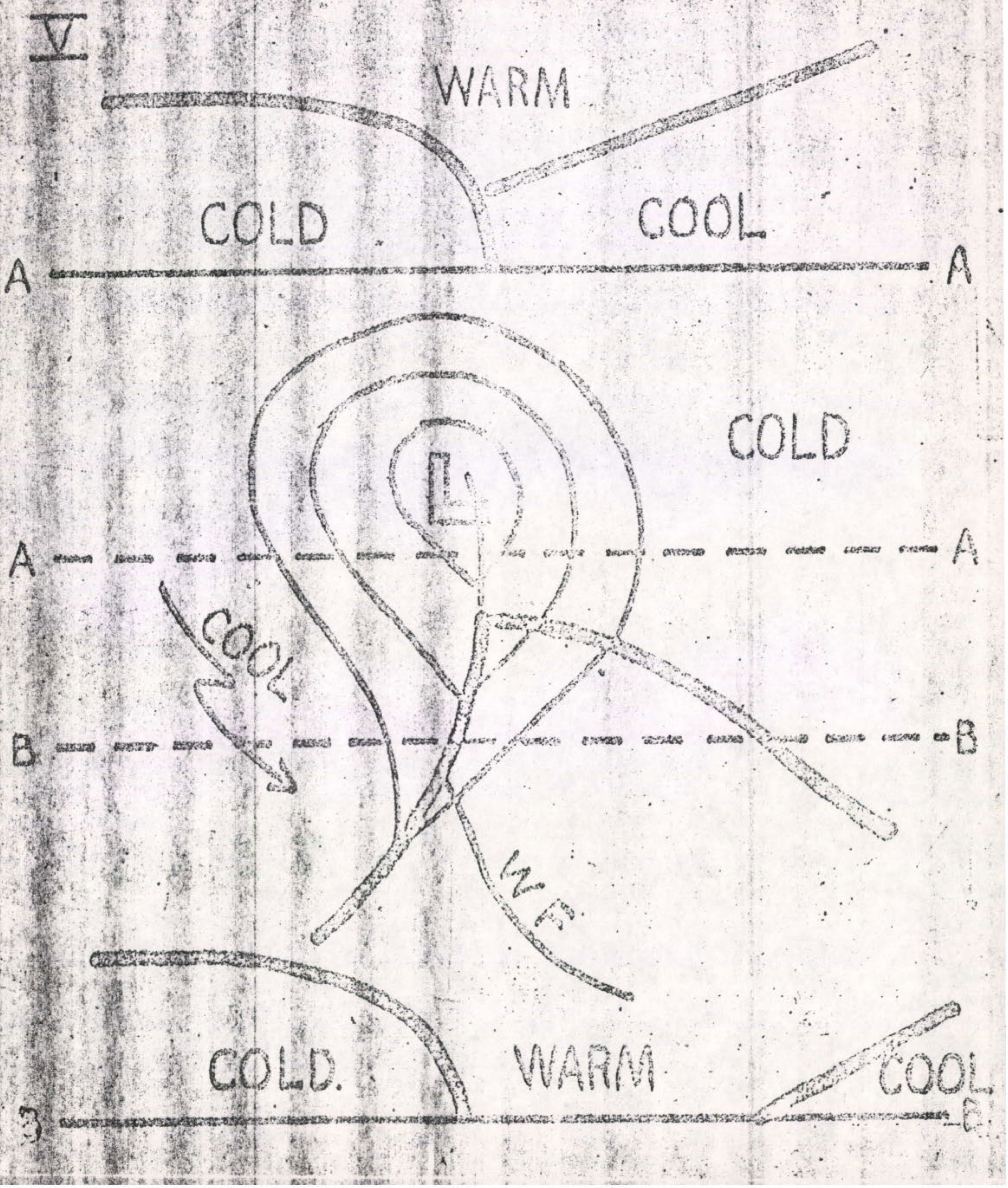
K - COLD

W - WARM

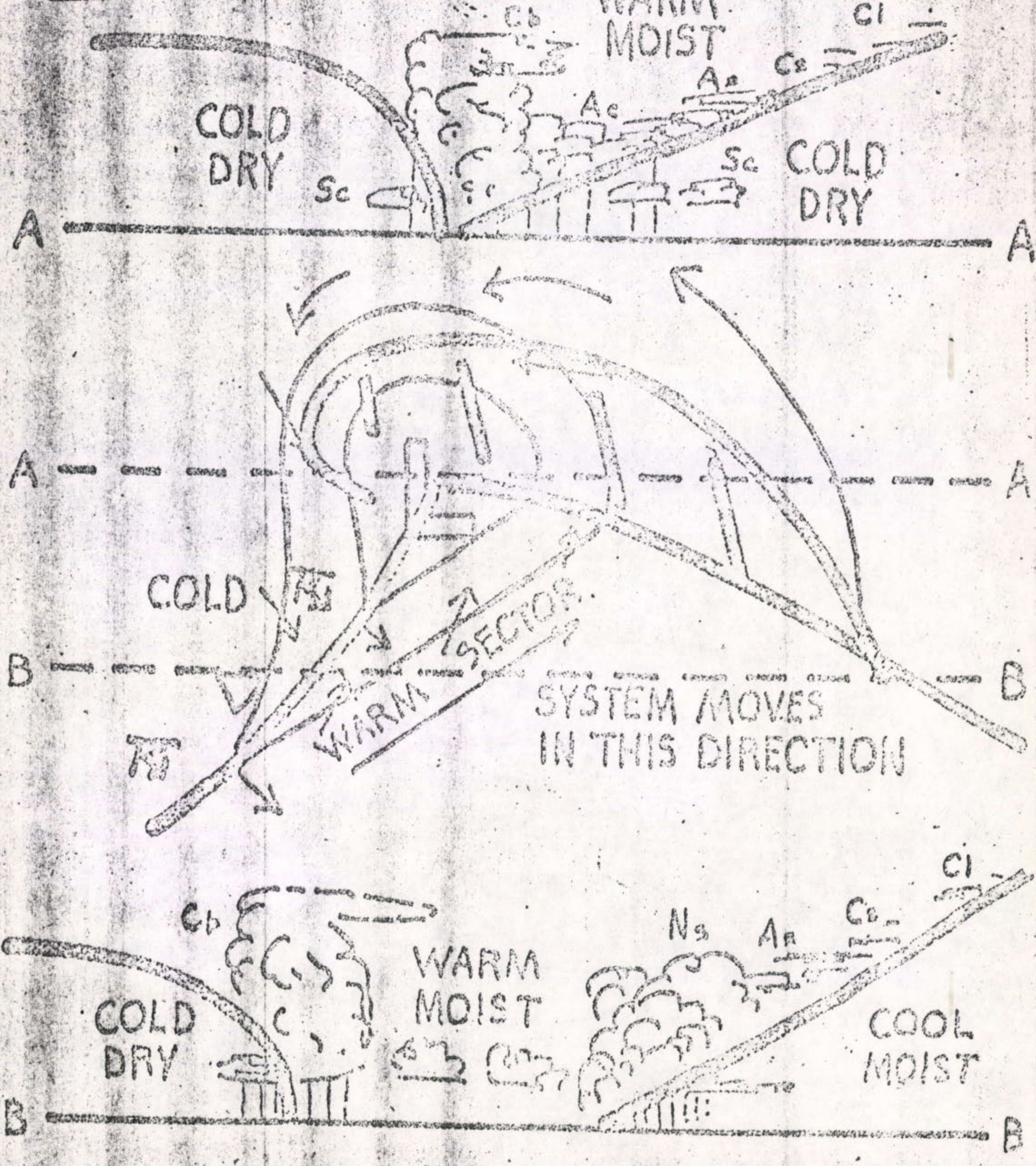
EXAMPLE:
AN "mPK" AIR MASS IS A MARITIME POLAR AIR MASS COLDER THAN SURFACE OVER WHICH IT IS PASSING

A

#12



IV



WARM
MOIST
Cb
Ci
Cs
As
Ac
COLD
DRY
Sc
Sc
COLD
DRY
A
A
A
A
COLD
B
B
WARM SECTOR
SYSTEM MOVES
IN THIS DIRECTION
Cb
Ns
As
Cs
Ci
WARM
MOIST
COLD
DRY
COOL
MOIST
B
B

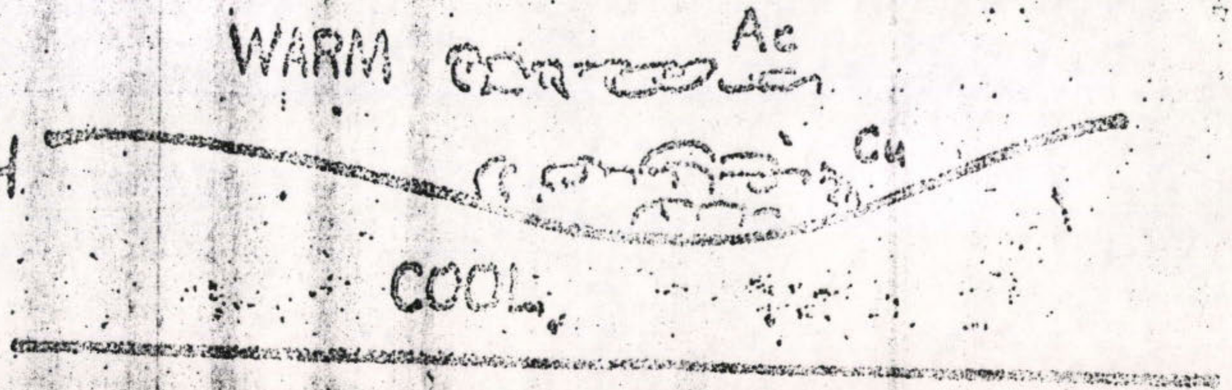
#1 [redacted]

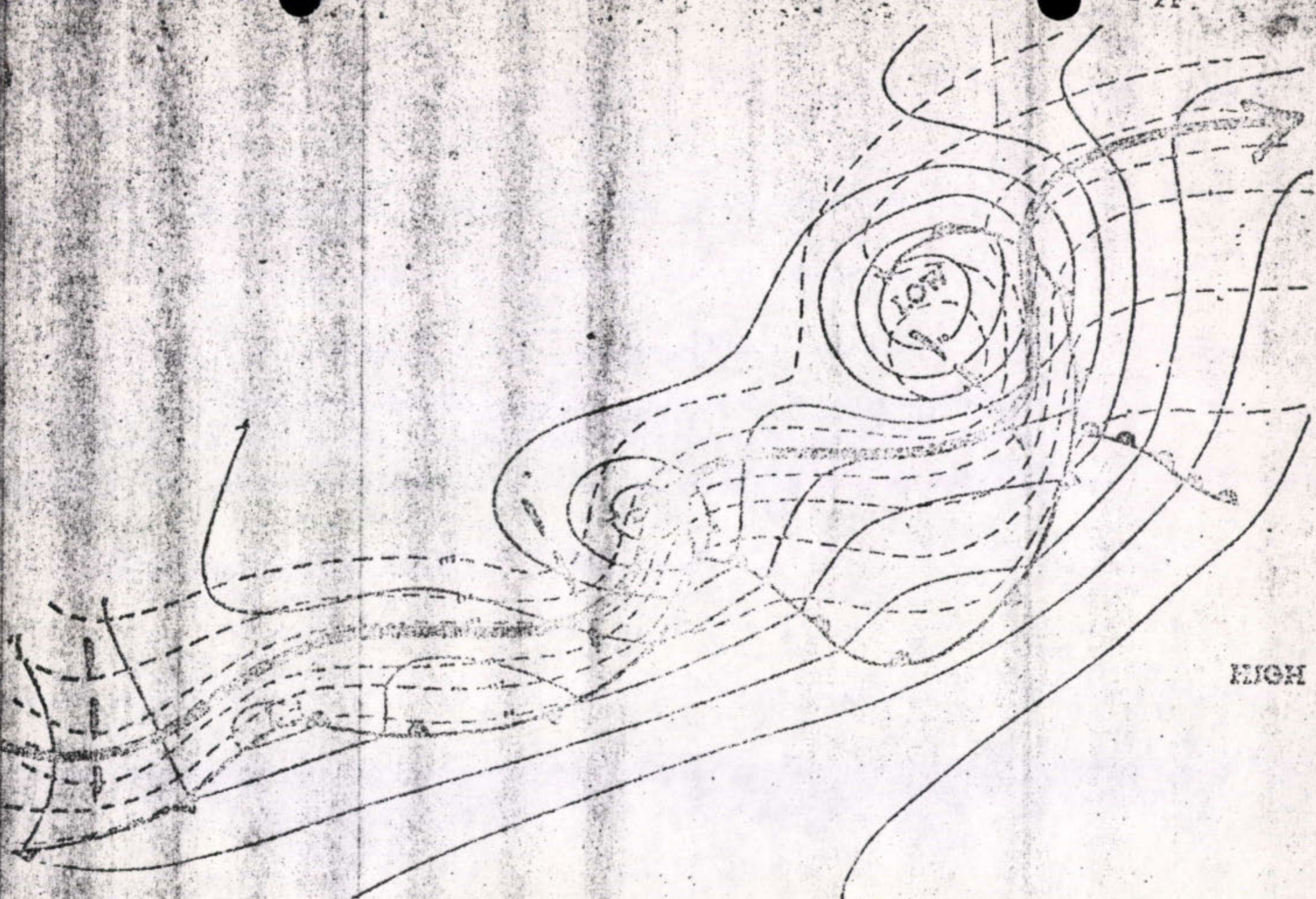
COLD OCCLUDED [redacted] FRONT

WARM-OCCLUDED FRONT

COLD-FRONT (LATE STAGE)

TROUGH ALOFT





FAMILY OF WAVES

Frequently, a series of waves will develop in a region of strong temperature contrast. Each will move away toward the east or northeast. Such a family of waves is shown in the illustration above. The one farthest east is the oldest and most developed. The wave farthest west is just beginning to develop. In the diagram, the solid lines are contours on the 1,000 mb. pressure surface. They are equivalent to isobars on a sea level chart. The dashed lines are mean isotherms between 1,000 mbs and 500 mbs, or approximately between sea level and 18,000 feet. Mean isotherms portray the distribution of average temperature in the entire layer. Also, since upper airflow tends to conform to the distribution of temperature, the dashed lines are approximately the streamlines of upper air. Although the "whirl" begins at the surface, if conditions favor a strong development, the rotation extends to fairly high levels. As rotation continues, and the cold and warm "tongues" wrap around each other, a mixing of airmasses gradually occurs. Temperature contrasts are weakened and the circulation dies away.

Relative humidity - Ratio of the amount of water vapor in the air compared to the amount it would have if the air was saturated.

Dewpoint Temperature - The temp to which air must be cooled in order for saturation to occur.

Wet bulb Temp - Temp air assumes by the evaporation of water into it.

Front - Boundary between two different air masses.

Types of Fronts:

Cold

Warm

Occluded

Stationary

Fronts form in troughs of low pressure.

2. THE ATMOSPHERIC GAS THAT HAS THE MOST PRONOUNCED EFFECT ON THE WEATHER IS:

A. OXYGEN

B. OZONE

C. NITROGEN

D. WATER VAPOR

The atmosphere is held to the earth by:

a. Charles Atlas

b. Glue

c. Gravity

d. Giant Helicopters

Atmospheric Pressure vs.

Altitude above Sea Level

	Pressure		
Height (feet)	lbs/in²	millibars	inches Hg.
100,000	0.15	10.5	0.31
50,000	1.68	116.0	3.42
18,000	7.34	506.0	14.94
10,000	10.11	696.8	20.58
sea level	14.70	1013.2	29.92

Air Motion is caused by several factors:

1. Uneven heating & cooling
2. Gravity
3. Rotation of the earth
4. Pressure gradients

3. IN THE NORTHERN HEMISPHERE THE WIND BLOWS:

A. COUNTER-CLOCKWISE AROUND HIGHS AND CLOCKWISE AROUND LOWS.

B. CLOCKWISE AROUND HIGHS AND COUNTER-CLOCKWISE AROUND LOWS.

C. CLOCKWISE AROUND BOTH HIGHS AND LOWS.

D. (A) IN SUMMER AND (B) IN WINTER.

Relative humidity - Ratio of the amount of water vapor in the air compared to the amount it would have if the air was saturated.

Dewpoint Temperature - The temp to which air must be cooled in order for saturation to occur.

Wet bulb Temp - Temp air assumes by the evaporation of water into it.

Front - Boundary between two different air masses.

Types of Fronts:

Cold

Warm

Occluded

Stationary

Fronts form in troughs of low pressure.

With the possage of a cold front in the Northern Hemisphere, winds shift _____

A. In a counterclockwise direction

B. A Counterclockwise direction

c. No shift, they are calm

d. Because of Coriolis effect

Warm air rises +
cold air sinks.

True

False

INSTRUCTOR'S LESSON PLAN

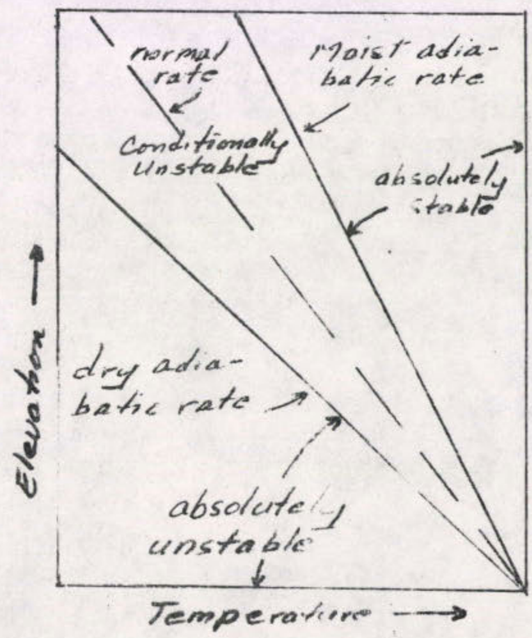
COURSE: Intermediate Fire Behavior PLACE: Fort Collins, Colorado
INSTRUCTOR: G. R. Miller DATE: March 16-18, 1971
TITLE OF LESSON: Stability & Vertical Motion
LENGTH OF LESSON: One hour
TRAINING AIDS: Overhead projector, easel and response cards
OBJECTIVES: To provide a basis for understanding both broadscale and local vertical air motion and to prepare for the application of this knowledge to fire control activities.

Time	Lesson Plan	Key point or aid
0800	The normal flow of air in the atmosphere tends to be horizontal. If this flow is disturbed, a stable atmosphere will resist any upward or downward displacement and will tend to return quickly to a normal horizontal flow. An unstable atmosphere, on the other hand, will allow these upward and downward disturbances to grow. The clearest example of such an unstable development in the atmosphere is the thunderstorm which grows as a result of a large and intensive vertical movement of air.	Greatest example of an unstable atmosphere is a thunderstorm.
	Atmospheric resistance to vertical motion, called "stability", depends upon the vertical distribution of the air's weight at any particular time. The weight of air depends upon its temperature. At a given pressure warm air is lighter than cold air. The term warm and cold in this instance is relative. For example the warm air may be 95 degrees while the "cold" air may be 85 degrees. If a parcel of air is warmer than its surroundings, it is forced to rise. A balloon filled with air at room temperature will not rise if released. However, if it is filled with air that is warmer it will rise and conversely, if it is filled with air that is colder, it will fall. In both cases the parcel of air is said to be "unstable" since it moves upward or downward when released. In the same manner that the balloon with warm air rises, the air which is heated near the ground on a hot summer day will also rise. The speed and vertical extent of the rising air will depend on the temperature difference between the rising air and its surroundings. The air will rise as long as it remains warmer than the surrounding air.	Warm air rises and cold air sinks.
	Lapse Rates	
0810	The term "lapse rate" is used frequently in the use and study of the stability of the air. What does the term actually mean? Lapse rate means a rate of	Lapse rate is a rate of change

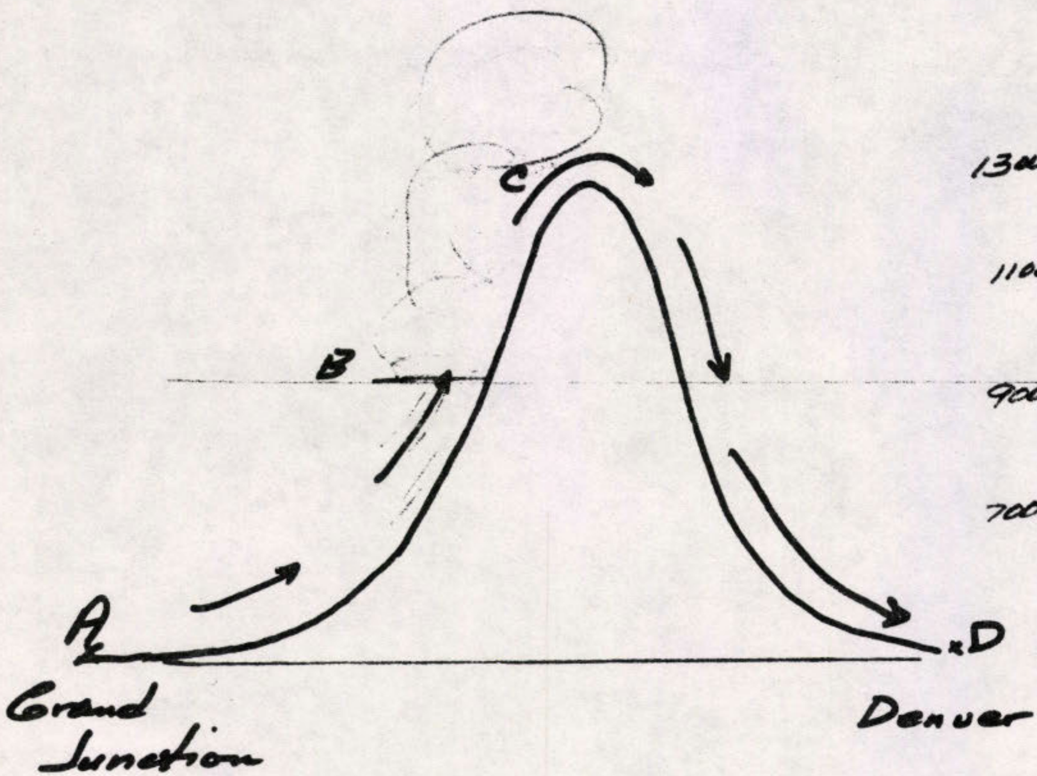
Time	Lesson Plan	Key point or aid
	change and in this case it means the rate of change of temperature with height, usually expressed in the number of degrees per thousand feet. There are four different kinds of lapse rates. (1) Dry adiabatic lapse rate, (2) Moist adiabatic lapse rate, (3) Dew-point lapse rate, and (4) the actual temperature lapse rate.	View graph Kinds of lapse rates
	When discussing lapse rates, air that has not reached the saturation point is said to be "dry" or "unsaturated". The degree of saturation of the air is expressed by the relative humidity. If the relative humidity is 70% then this means that 70 percent of the moisture necessary for saturation is present. Note that the term "dry" refers to any air that is not completely saturated.	Dry air is air that is unsaturated.
0815	<u>Dry Adiabatic Lapse Rate</u> When unsaturated air rises, its temperature decreases at the rate of 5½ degrees per thousand feet, regardless of what is causing the air to rise. If the air is rising due to heating from below or if it is forced up over a mountain by the wind flow, as long as the air is unsaturated it will cool at the constant rate of 5½ degrees per thousand feet. This is know as the dry adiabatic lapse rate. The word "adiabatic" means that the temperature change takes place without any addition or loss of heat from the air. The temperature decreases because the air expands and the heat within the parcel is used to expand the gas, causing a drop in temperature. If the air is forced to descend for any reason the temperature of the air will warm at the rate of 5½ degrees per thousand feet for the same reason.	Dry adiabatic lapse rate. 5½ degrees per thousand feet.
0820	<u>Moist Adiabatic Lapse Rate</u> We have mentioned that the amount of water vapor that a given volume of air can hold is determined by its temperature and that warm air can hold more water vapor than cold air. It follows, then, that we can take a volume of air with a given temperature and by cooling the air, we can reduce the amount of water vapor that it can hold. If we continue to cool the air we will reach a point where the water vapor capacity of the volume of air is the same as the actual water vapor present in the air. The temperature at this point is called the saturation temperature or dewpoint temperature.	Moist adiabatic lapse rate

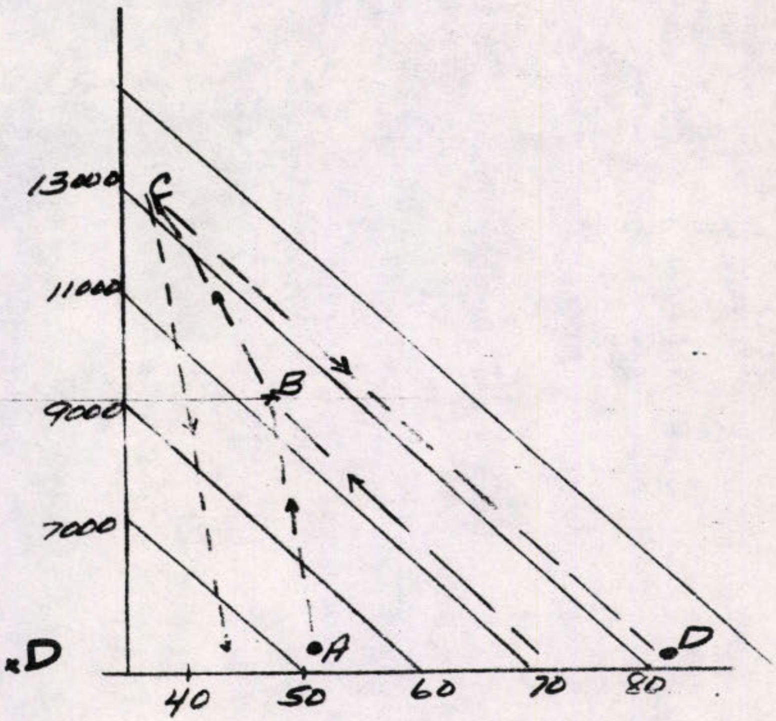
Time	Lesson Plan	Key point or aid
	When water vapor is formed from evaporation of liquid water it requires a certain amount of heat, whether this is done by placing a pan of water on a stove or whether the evaporation took place at the ocean surface. When this water vapor is condensed back into a liquid the amount of heat that was required for evaporation is released. When we cool air beyond its saturation point and liquid water is condensed out, this latent heat of condensation is released to the air and raises the temperature of the air.	Condensation releases heat into the air
	As mentioned a parcel of dry air when lifted cools at 5½ degrees per thousand feet until it becomes saturated. As we continue to lift the parcel above the saturation level it would continue to cool at the dry adiabatic rate if it were not for the heat released by the condensation of liquid water caused by cooling the parcel beyond the saturation temperature. The addition of this heat makes the air cool at a lesser rate than the dry adiabatic rate. This lesser rate is called the moist adiabatic lapse rate and varies from 2 to 5 degrees per 1000 feet. This cooling rate is not constant because the amount of heat added to the air through condensation is not constant. We mentioned that warm air contains more moisture than cold air. Note, however, that the moist adiabatic lapse rate is not really an adiabatic process since we are adding heat to the parcel.	Moist adiabatic lapse rate is 2 to 5 degrees per thousand feet
0825	<u>Dewpoint lapse rate</u> The dew point temperature of a parcel of air also changes as the air rises or descends. This lapse rate is about 1 degree per thousand feet and is constant for all altitudes. This lapse rate does not contribute directly to the stability of the air but we use it to determine the point where the air will become saturated. If unsaturated air cools at 5½ degrees per thousand feet as it rises, and the dewpoint cools at 1 degree per thousand feet, it is obvious that the two temperatures will converge and meet at some point above. This point is known as the condensation level. Above this level the temperature and dewpoint temperature are always or very nearly the same. Meteorologists use the above concept to determine the height of cumulus clouds.	Dew point lapse rate or mixing ratio. Lifting condensation level. View graph
0830	<u>Actual Lapse rate</u> Keep in mind that the above lapse rates are process lapse rates. They only occur when we force the air to ascend or descend. We are concerned with the	

Time	Lesson Plan	Key point or aid
	actual rate of temperature change that exists in the atmosphere at a given time and place. This lapse rate is measured with instruments that ascend with a balloon to an altitude of about 100,000 feet. While ascending, the instrument radios continuous information to a ground station on temperature, pressure and relative humidity. During this time other equipment is also measuring wind speed and direction for various levels of the atmosphere through which the balloon is passing.	Radiosondes measure actual or observed lapse rates.
	This actual or observed lapse rate varies widely. The temperature generally decreases with elevation, but at times the air may actually become warmer as the elevation increases. This condition is known as an <u>inversion</u>.	Inversion defined
0840	The stability of the air depends on whether it is saturated or unsaturated: (1) If the observed lapse rate is greater than (slopes more to the left) the dry adiabatic, then the air is said to be <u>absolutely unstable</u>. (2) If the observed lapse rate is less than the moist adiabatic lapse rate (slopes less to the left) then the air is said to be <u>absolutely stable</u>.	Absolutely unstable, absolutely stable and conditionally stable or unstable
	(3) If the observed lapse rate lies between the dry adiabatic and the moist adiabatic rates, then the air is said to be <u>conditionally unstable</u>. This simply means that as long as the air remains unsaturated it is stable, but if it is lifted to the point where it becomes saturated, it then becomes unstable.	View graph



Time	Lesson Plan	Key point or aid
	Note that statements (1) and (2) define a condition where no work is done on the parcel. The air is stable or unstable without any outside influence. Statement (3) describes a condition that may be stable or unstable but some work must be done on the air to cause a change. The air may be lifted by mechanical means (forced over a mountain) or the air near the surface may be heated and caused to rise (work being done by bouyancy forces). Observed lapse rates often fall into this category.	Most lapse rates (observed) are conditionally unstable.
0850	Let's use these lapse rates and processes to show why warm air is a common occurrence along the east slopes of the Rocky Mountains. Let's follow a parcel of air from Grand Junction to Denver along a moderate to strong southwesterly wind. (See figure next page.) The air is at an elevation of 5300 feet above sea level as it passes Grand Junction (point A). At this point its temperature is 70 degrees F, dewpoint 51 degrees F and relative humidity 50%. As the air is forced up the west slopes of the mountains it begins to cool at the dry adiabatic rate ($5\frac{1}{2}^{0}$ F per thousand feet) until it reaches 9300 feet where the air becomes saturated (point B). The temperature and the dewpoint are about 48 degrees F and the relative humidity is 100%. As the air continues to rise up the slopes it cools at the moist rate (about 2 degrees F per thousand feet) and since its water vapor capacity continues to decrease, the excess vapor is condensing out in liquid form. As the air parcel reaches the crest of the divide (point C) it has attained an altitude of about 13,000 feet and at this point its temperature is 37 degrees F, dewpoint is 37 degrees and the relative humidity is 100%. As the air begins to descend the east slopes of the mountains it warms at the dry adiabatic rate because as it descends, its temperature increases, and because of the increase in temperature it is no longer saturated. As the parcel continues to descend it warms at the rate of $5\frac{1}{2}$ degrees per thousand feet until it reaches the Denver area (point D) at an elevation of 5300 feet, or approximately the same elevation as it began its journey. Its temperature at this point is 81 degrees F, dewpoint is 44 degrees F and the relative humidity is 26%. Note that the temperature has increased 11 degrees and the relative humidity has decreased 24% during its journey over the mountains. The increase in temperature is the result of the heat that was added to the parcel of air due to the condensation of water vapor into liquid water droplets as the air ascended between 9,300 feet and 13,000 feet. If the parcel had	


A
B
C
D
Grand Junction
Denver


13000
11000
9000
7000
C
B
A
D
40
50
60
70
80

Time	Lesson Plan	Key point or aid
	never reached saturation its temperature would have been the same at Denver as it was when it passed over Grand Junction. The decrease in relative humidity is partially due to the increase in temperature and partially to the loss of water vapor during the condensation process.	
0900	If we consider the wind speed along with the condition described above we have the well know "Chinook" conditions that we experience during the winter and spring months along the east slopes of the Rockies.	Chinook winds

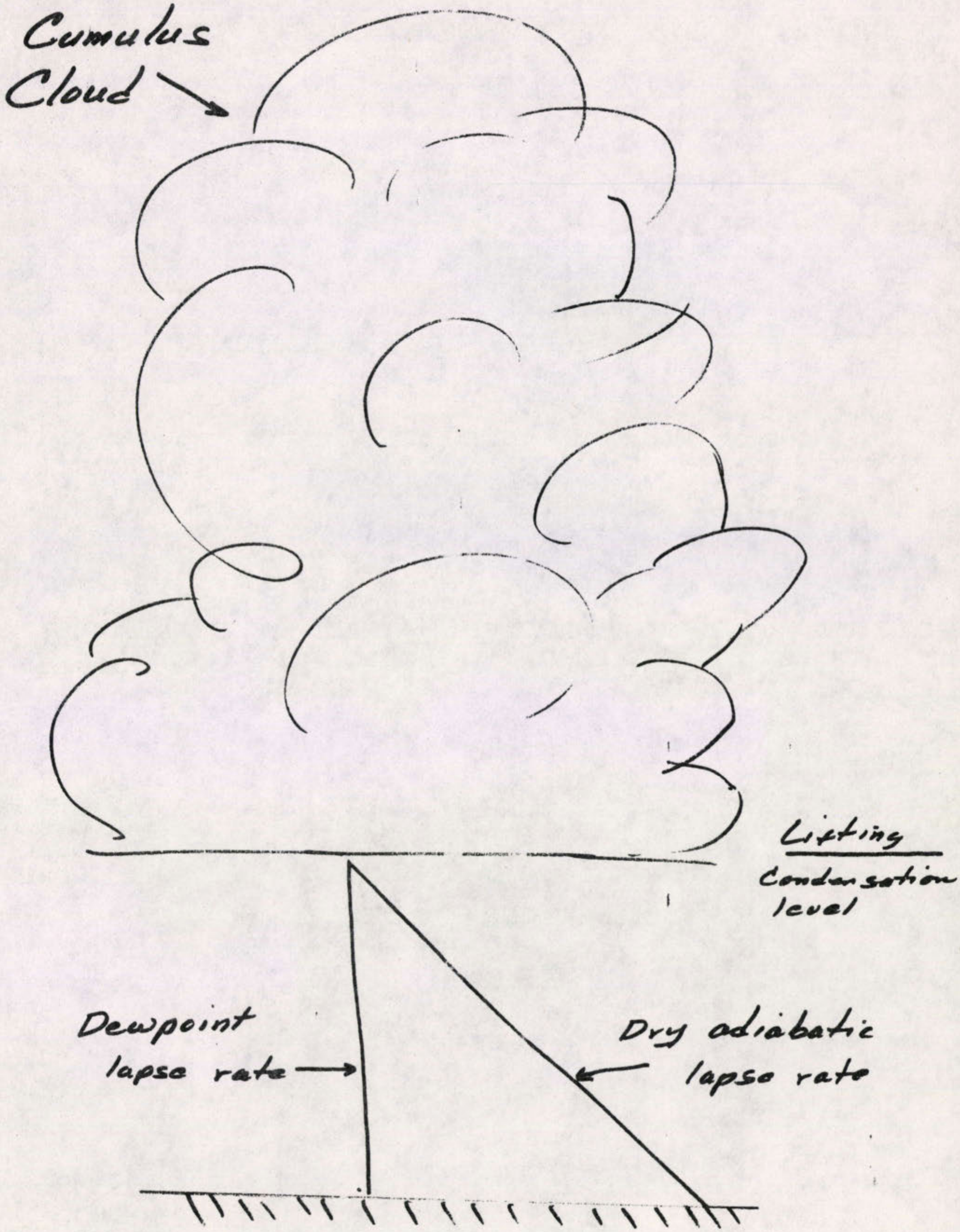
Some Kinds of lapse rates:

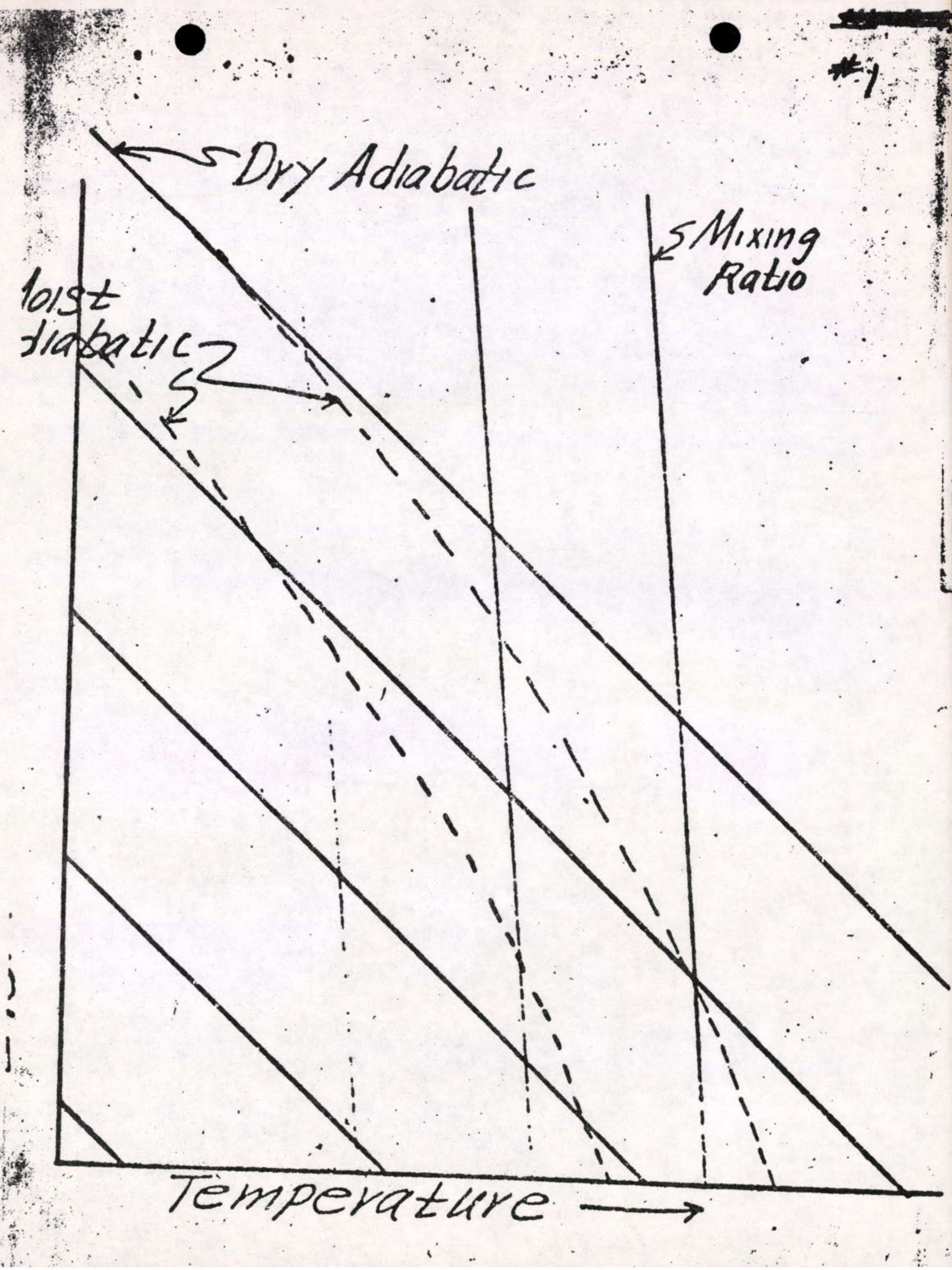
(1) Dry adiabatic

(2) Moist adiabatic

(3) Dewpoint or mixing ratio

(4) Actual temperature


Cumulus
Cloud
Lifting
Condensation
level
Dewpoint
lapse rate
Dry adiabatic
lapse rate



#1
Dry Adiabatic
Mixing Ratio
loist
diabatic
Temperature

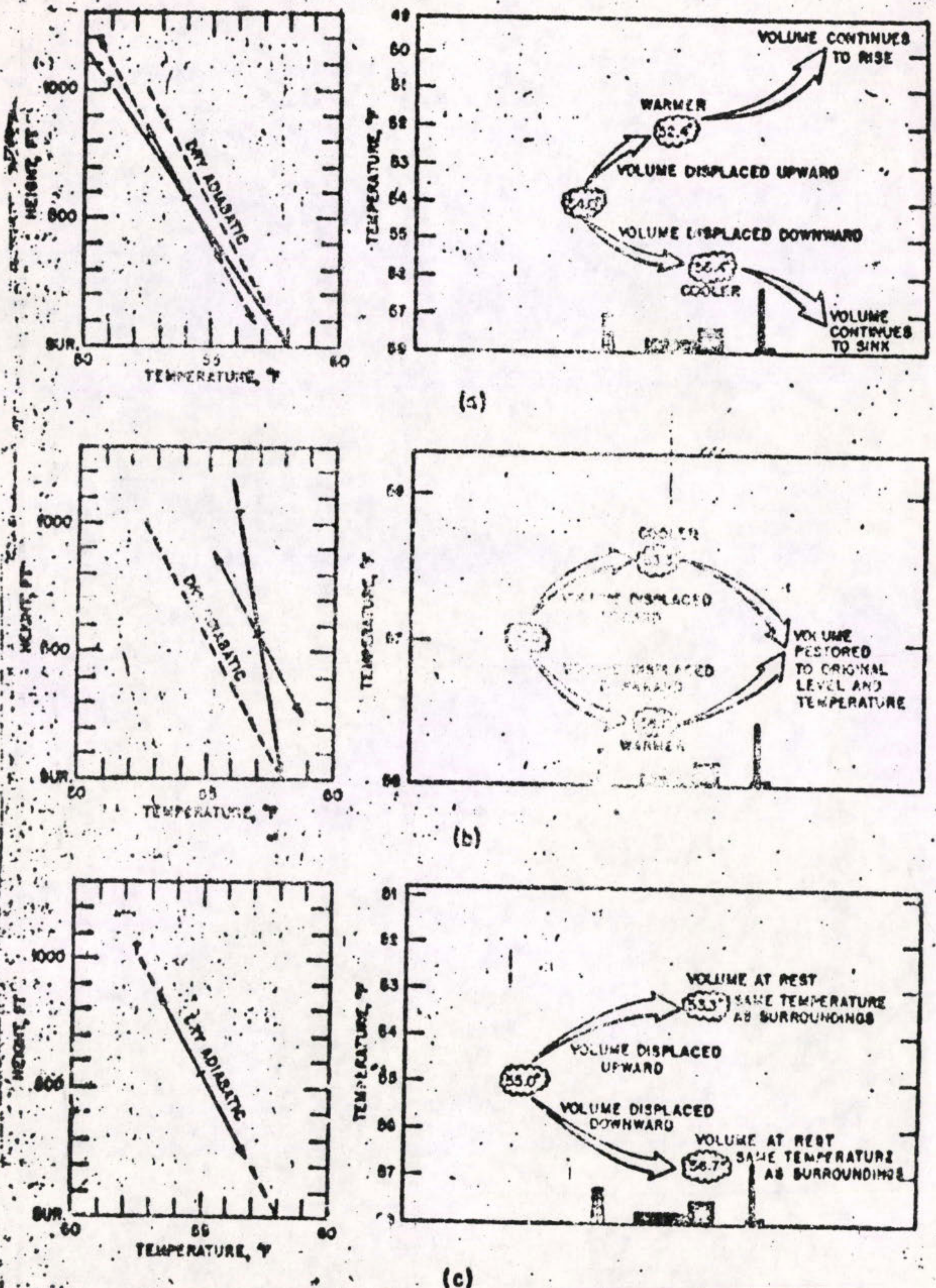
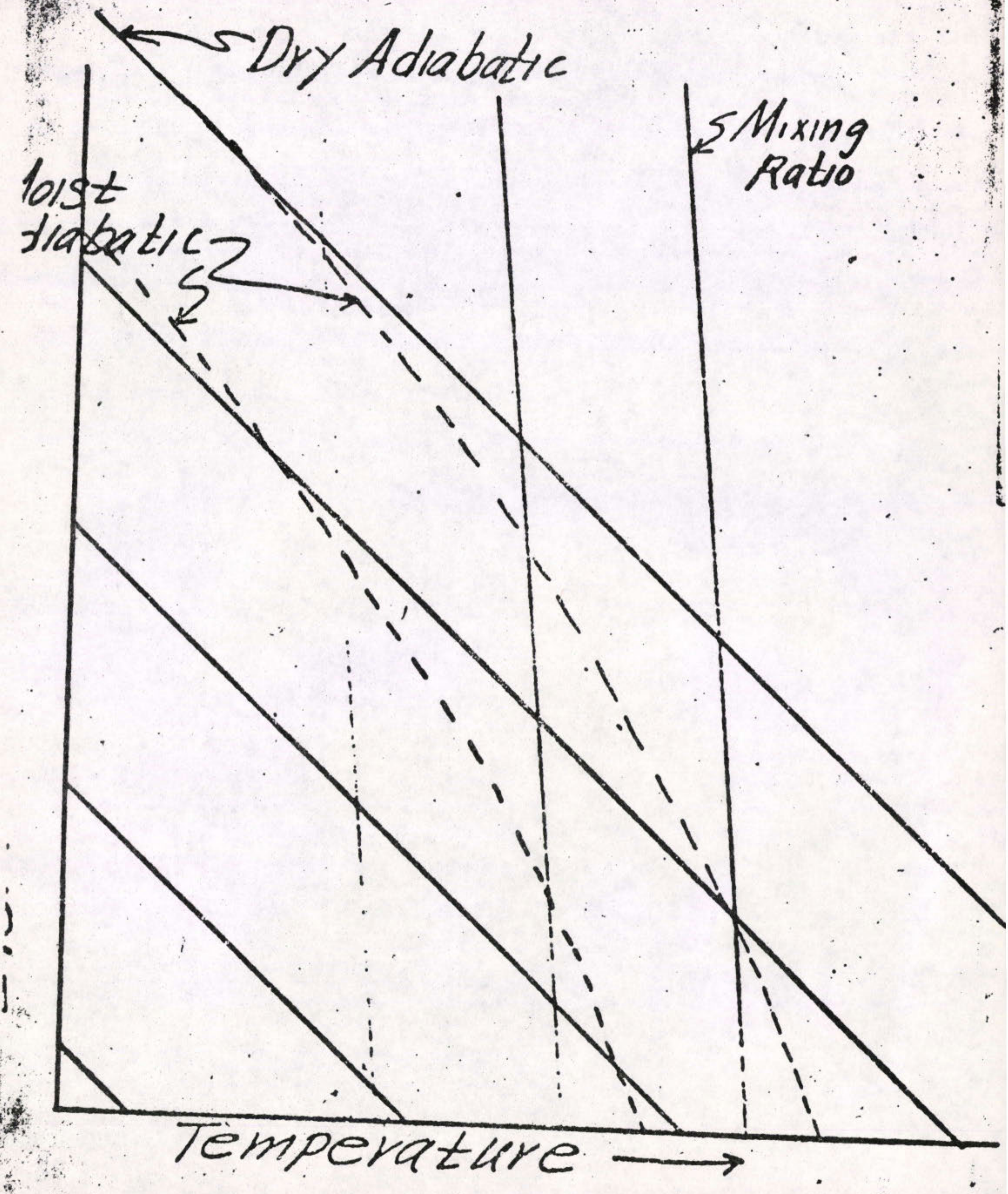


Fig. 3.17—Effects of lapse rate on displaced air volumes. (a) Unstable lapse rate. (b) Stable lapse rate. (c) Neutral lapse rate.


Dry Adiabatic
Mixing Ratio
loist
diabatic
Temperature

COURSE: Intermediate Fire Behavior | PLACE: Fort Collins, Colorado
DATE: March 16-18, 1971
SUBJECT: Fire Weather Forecasts | INSTRUCTOR: G. R. Miller
TRAINING AIDS: View graph, easel and response cards.
OBJECTIVES: (1) to improve skill in the interpretation of forecasts, (2) to encourage regular systematic use of fire weather forecasts and (3) maintain harmonious relationship with you and the fire weather forecaster.

TIME	LESSON PLAN	Key point or aid
0900	The National Weather Service of the National Oceanic and Atmospheric Administration (NOAA) is responsible for providing forecasts of fire weather to Federal and State people in charge of protecting our forests and rangelands from the devastations of fire. Within the National Weather Service, Fire Weather Meteorologists are specifically assigned this duty.	Responsibility of offices assigned fire weather duties.
0905	Throughout Region II of the Forest Service there are six offices of the National Weather Service that are assigned fire weather forecasting responsibilities. These include Denver, which is also a Coordination Center, Cheyenne, Sheridan and Lander, Wyoming and Rapid City, South Dakota; North Platte, Neb. A fire weather meteorologist has been directly assigned to the station or local station personnel have the responsibilities.	Fire Weather offices in Region II of the USFS.
0910	Regular fire weather forecasts or <u>presuppression</u> forecasts are made daily at the above offices starting in Spring and ending in the fall when danger is reduced due to snowfall. Depending on local requirements and station personnel, these presuppression forecasts are issued in the afternoon between 2 and 4:30 PM. In addition to the presuppression forecasts, fire weather meteorologists issue special forecasts and warnings. <u>Special</u> forecasts are forecasts for controlled burns, "going" fires, special spraying projects, etc. Fire Weather Special Forecast Request form or WB Form 653-1 should be used as a guide when a Forester requests a special forecast. There is some pertinent information that should accompany the special forecast request. This information would include LOCATION, DRAINAGE NAME, EXPOSURE, SIZE, ELEVATION, FUEL TYPE and if fire is ON THE GROUND OR CROWNING. Any inclusion of observations, needless to say, is very helpful. These forms can be obtained from your local fire weather meteorologist.	Types of fire weather forecasts. View graph Special forecast requests. WB form 653-1. Essential items.

TIME	LESSON PLAN	Key point or aid
	A warning is issued when the forecast weather is expected to result in a marked increase to high or extreme fire danger. Fire control agencies should define the conditions under which they want these headings added to the forecasts. In some areas these warnings are termed "Red Flag Alerts".	Warnings
0920	Presuppression forecasts issued by fire weather offices vary from station to station somewhat. That is the format may be different. The items forecast are the same. They include:	Items forecast
	(1) Sky cover, fog and visibility. The amount and time of beginning and/or change of each element.	
	(2) Temperature. Maximum (minimum for nighttime periods). In some areas a forecast change is added to the temperature, such as, "Temp up 6".	
	(3) Relative Humidity. Minimum (maximum for night time periods). In some areas a forecast change in humidity is added to the humidity as it is for temperature, such as, "Humidity down 10".	View graph
	(4) Wind. Direction and speed of the wind during the most hazardous part of the day, or at other times as specified in the forecasts. Maximum gusts erratic surface winds, updrafts, or windshifts expected with thunderstorms, swelling cumulus, cold front passages, or other instability-producing phenomena should always be mentioned.	
	(5) Precipitation. Type, amount, if feasible, extent and time of occurrence of all precipitation should be included. Precipitation is generally expressed as a point probability of occurrence.	
	(6) Lightning or Thunderstorms. Probability, extent and time of occurrence. This is the percent of area subject to lightning rather than the area affected by a single stroke. This simply means that with a given thunderstorm the area subject to lightning is the area covered by the thunderstorm.	
0930	These are the items mentioned in presuppression forecasts. As mentioned, they may vary from local to local. Any differences are usually so designated in the local fire weather Operating Plan.	
	A Fire Weather Map Discussion is issued in the morning and the afternoon by the fire weather office in Denver. This is a synopsis of meteorological factors that will be effecting the forecast areas of Colorado	Fire Weather Map Discussion

TIME	LESSON PLAN	Key Point or aid
	and Wyoming. It is not a forecast. It may contain technical terms since it is for digest of the fire weather forecasters at Lander, Cheyenne and Sheridan. Pertinent items having to do with fire control will be mentioned in the main fire weather forecast which is issued at a later time.	
0935	Meteorology is not an exact science. It will be some years yet before it is. Thus, forecasts will at times not turn out as expected. What should you do in this case? It is easy to criticize and complain, but in the meantime you are doing a disservice to you and your meteorologist. He may have no knowledge that his forecast is "way out in left field" while the ball game is being played in right field!! You should inform him that weather elements have not developed as expected. Unless he is an arrogant, cantankerous and recalcitrant old clod, he will be very grateful for your information. He will issue an amendment or revision.	Handling of bad forecasts.
0940	Large project fires are dependent upon localized weather information for their control. Available in the Western Region of the National Weather Service are <u>Fire Weather Mobile Stations</u>. These are exactly what the term suggests. A fire weather meteorologist is dispatched to the scene of the fire in order to give the Fire Boss timely forecasts of localized weather conditions. The closest ones available to Region II of the USFS are at Salt Lake City, Utah; Boise, Idaho; Missoula and Billings, Montana. When it is deemed that a fire will reach "major" proportions, a Fire Weather Mobile Station should be ordered. This will be done through your local fire weather meteorologist.	Fire Weather Mobile Stations
	The importance of these units can not be stressed enough; just ask those fire control people who have been in contact with them.	
0950	Occasionally you will need forecasts that cover a longer period of time than the normal 24 to 36-hr presuppression forecast. The National Weather Service can, with some degree of accuracy, predict the weather five days in advance. This is dependent on the type of weather regime currently being experienced. These five-day forecasts are disseminated every afternoon on the Colorado and Wyoming teletype circuit. They can be obtained from the local SO (Supervisor's Office).	Long range forecasts

TIME	LESSON PLAN	Key Point or aid
	Fire Weather forecasts are only as good as the observations upon which they are based. You, as a fire control individual should see that the fire danger stations on your district are accurately and to the best of their knowledge, reporting the weather. If you note discrepancies, you should try to alleviate them or ask your fire weather meteorologist for assistance.	
1000	Fire weather meteorologists amass a great deal of information and digest many facts before arriving at a forecast of pending weather events. I would not try to "second-guess" the fire weather forecasts you receive. You will be right occasionally, but more often you will be wrong. A fire weather forecast is the best product that a meteorologist can put together for future events. He has spent many hours making it. Learn how to use to the best of your ability.	

WB FORM 653-1
(11-63)
(PRES. BY
WBM III-B-40)

U.S. DEPARTMENT OF COMMERCE
WEATHER BUREAU

FIRE WEATHER SPECIAL FORECAST REQUEST

(See reverse for instructions)

I - REQUESTING AGENCY WILL FURNISH:

1. NAME OF FIRE OR OTHER PROJECT	2. CONTROL AGENCY	3. REQUEST MADE TIME #	DATE

4. LOCATION *(By 1/4 Sec - Sec - Twp - Range)*	5. DRAINAGE NAME	6. EXPOSURE *(NE, E, SE, etc.)*

7. SIZE OF PROJECT *(Acres)**	8. ELEVATION* TOP	BOTTOM	9. FUEL TYPE	10. PROJECT ON: ☐ GROUND ☐ CROWNING

11. WEATHER CONDITIONS AT PROJECT OR FROM NEARBY STATIONS *(See example on reverse)*

PLACE	ELE-VATION	OB TIME#	WIND DIR.-VEL.	TEMP. DRY	TEMP. WET	† *(Lv. Blank)* RH	† *(Lv. Blank)* DP	REMARKS *(Indicate rain, thunderstorms, etc. Also wind condition and 10ths of cloud cover.)*

12. SEND FORECAST TO:	PLACE	VIA	ATTN: *(Name, if applicable)*

II - FIRE WEATHER FORECASTER WILL FURNISH:

13. FORECAST AND OUTLOOK TIME # AND DATE: ______

NAME OF FIRE WEATHER FORECASTER	FIRE WEATHER OFFICE

III - REQUESTING AGENCY WILL COMPLETE UPON RECEIPT OF FORECAST

IV. FORECAST RECEIVED:	TIME #	DATE	NAME

Explanation of symbols:
- # Use 24-hour clock to indicate time. Example: 10:15 p.m. =2215; 10-15 a.m. = 1015.
- * For concentrations (as groups of lightning fires) specify "Concentration"; then give number of fires and size of largest. If concentrations are in more than one drainage, request special forecast for each drainage.
- † No entry necessary. To be computed by the Fire Weather Forecaster.

INSTRUCTIONS

I - Fire Control and other Project Personnel:

1. Complete all items in Section I each time a special forecast is desired.

   a. Example of Weather Conditions:

PLACE	ELE-VATION	OB TIME	WIND DIR.-VEL.	TEMP.		†(Lv. Blank)		REMARKS
				DRY	WET	RH	DP	
Fire camp	2080'	1125	NW 16	85	62			Scattered clouds, 2/10ths Cumulus. Thunderstorm ended 2 hours ago. Wind gusty, direction varies from NW to N.

2. Transmit in numerical sequence to the appropriate Fire Weather Office. (The Fire Weather Forecaster will complete the special forecast as quickly as possible and transmit the forecast and outlook to you by the method requested.)

3. Upon receipt of special forecast, complete Sections II and III.

4. Retain completed copy of form for your records.

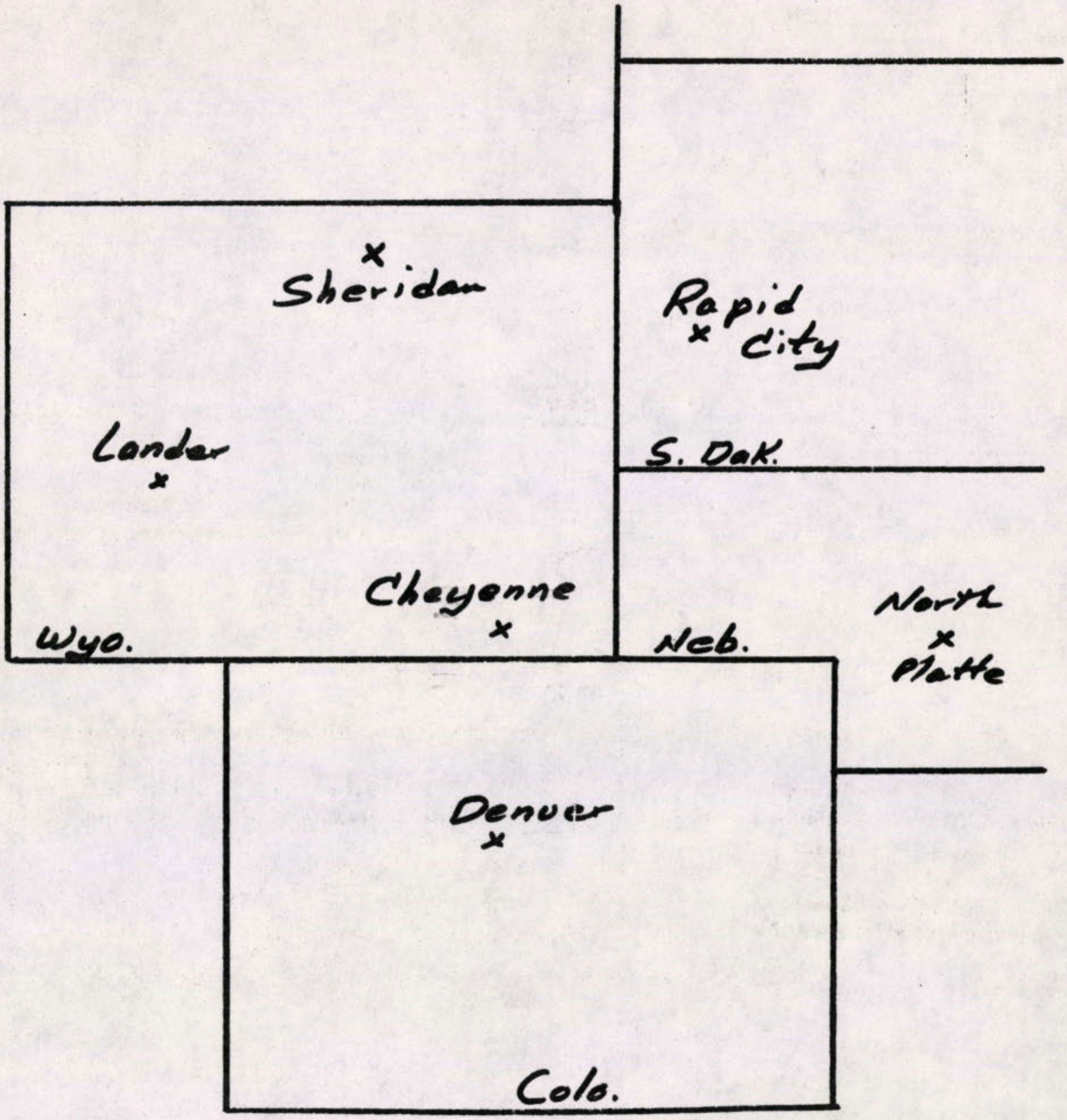
5. Should conditions occur that are not correctly forecast, notify the Fire Weather Forecaster by phone or radio.

II. ALL RELAY POINTS should use this form to ensure completeness of data and completeness of the forecast. A supply of the form should be kept by each dispatcher and all others who may be relaying requests for forecast or who may be relaying the forecast.

III. Forms are available from your local Weather Bureau Fire Weather Office. They may also be reproduced by forest or range agencies as needed, entering the phone number and radio identification, if desired.

IV. Fire Weather Forecasters:

1. Copy information received on this form.
2. Complete special forecast as quickly as possible and return forecast and outlook by the method requested.
3. Supply pertinent radar scope information whenever possible, indicating time of radar report.
4. Complete "RH/DP" columns in Item eleven.
5. Retain copy for record purposes.



National Weather Service Offices assigned fire weather forecasting responsibilities. (Region II USFS)

NOAA stands for:

(1) Noah's Ark

(2) Nasty Old Abominable Apes

(3) National Organization for Awful Alcoholics

(4) National Oceanic and Atmospheric Administration

Items included in Presuppression

Forecasts:

(1) Sky cover

(2) Temperature

(3) Relative Humidity

(4) Wind

(5) Precipitation Probability

(6) Lightning Probability

WB FORM 653-1
(11-63)
(PRES. BY
WBM (II-B-40)

U.S. DEPARTMENT OF COMMERCE
WEATHER BUREAU

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II - FIRE WEATHER FORECASTER WILL FURNISH:

13. FORECAST AND OUTLOOK — TIME # AND DATE: ____________

NAME OF FIRE WEATHER FORECASTER	FIRE WEATHER OFFICE

III - REQUESTING AGENCY WILL COMPLETE UPON RECEIPT OF FORECAST

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III

SUBJECT : Meteorology

LESSON : Clouds as Indicators III-D

OBJECTIVE: The trainee will better anticipate the weather that may affect fire behavior and can recognize and describe the significance of clouds.

TIME : $1\frac{1}{2}$ hours

AIDS : 69 35mm slides
Movie "Cloud Motions for Fire Behavior Trainees"

July 1967

Prepared by

Owen P. Cramer, Meteorologist
Pacific Southwest Forest & Range Experiment Station

Slide 1 Clouds are different things to different people. To the pilot, the mariner, and the fire behavior expert, clouds are Nature's signboards, advertising current and expected weather. The trouble with signboards of this kind is that you have to know how to read them before they can be of much help. So we're going to study these signboards for two reasons: (1) so that you can better anticipate the weather that may affect the behavior of any fire, and (2) so that you can recognize and describe the significant things you see to someone else.

Clouds are important to fire control people because they give us four kinds of information:

Slide 2 (1) Clouds indicate airmass properties such as stability, moisture, and upper winds. These altocumulus castellanus indicate a moist, unstable layer above 10,000 feet. Incidentally, altocumulus castellanus clouds often precede the formation of thunderstorms.

Slide 3 (2) Clouds indicate developing or approaching weather, for example, the thunderstorm.

Slide 4 (3) They indicate atmospheric motion. This stationary wave cloud indicates a pattern of horizontal and vertical winds that may extend to the surface.

Slide 5 (4) Some clouds tell the history of weather in the airmass. These heavy cirrus were formed by thunderstorms a day or so before.

We will go into these indications in more detail in a few minutes, but first we need to check some names. You get more out of the game if you can recognize the players as well by name as by shape and action. The following cloud names are used singly or in a combination.

Slide 6 Stratus or strato clouds are basically flat and in rather thin sheets with little pattern.

1/ Most of the cloud pictures used with this lecture are from the U.S. Forest Service, Forest Fire Research at Missoula and Portland, and were taken by John H. Dieterich and Owen P. Cramer.

S' e
'

Cumulus means a heap. It is also applied to clouds showing patterns of rolls, tufts, or stacks.

Slide
8
Slide
9

Cirrus means hair and applies to ice crystal clouds. The sun's disk is quite diffuse through ice clouds in contrast to clear edges when viewed through water-drop clouds. A more important type of cirrus is this dense anvil-top remnant.

Slide
10

Nimbus is a rain cloud, a term usually used with other cloud names to describe precipitating types.

Slide
11

Alto is a prefix used to denote clouds that are predominantly water-drop clouds at high elevations where the temperature is below freezing.

Slide
12

Fracto is a prefix meaning fragmentary. It describes low cloud fragments or shreds that have no definite shape.

Slide
13

Castellanus are small heaps at high elevation--a type of alto-cumulus.

Slide
14

Mamma are pouch-shaped clouds that descend from beneath thunderstorm anvil tops, hence usually indicate that a thunderstorm is close by. Their motion is gentle downward with the leading edge of falling precipitation.

Slide
15

Virga are streaks of precipitation falling but not reaching the ground.

Slide
16

Lenticular or standing wave clouds are lens-shaped and are common as cap clouds over mountain peak or over the peak of a wave in the airflow pattern.

Slide 17 The more common cloud types are shown in this chart. Clouds are usually divided into four groups: low, middle, high, and clouds of vertical development. Low, middle, and high are usually defined in terms of their elevation, but this is highly variable between seasons and bewween airmasses. The elevation scale shown here could be doubled for warm summer airmasses. More important than elevation are cloud shape, texture, association, and evolution.

Low clouds usually are within 10,000 feet of the surface, are made up of water droplets, and may have large pattern features. The typical types are stratus, stratocumulus, and cumulus of fair weather.

Middle clouds are higher, commonly 10,000 to 20,000 feet above the surface, and are composed of supercooled water droplets, i.e., with temperatures below freezing. Ice crystals may also be present. Unlike water in your ice tray, cloud droplets may remain liquid to -39°F. Principle types are altostratus and altocumulus. Patterns are finer and cloud elements smaller than in low clouds.

High clouds are composed of ice crystals and typically are above 20,000 feet. Types include cirrostratus, rarely cirrocumulus, and several kinds of cirrus.

Clouds of vertical development describe the cumulonimbus or thunderstorm which may have a vertical extent of 50,000 feet. It is composed of water droplets in lower portions and ice crystals above.

Now we are going to get more specific and talk about a few clouds that are particularly important to fire control people. These are: (1) clouds indicative of stability; (2) clouds associated with thunderstorms; (3) clouds indicative of wind; (4) clouds associated with an approaching low pressure storm system.

Slide 18 Here are the indicators of unstable air, that is, air that has a tendency to support vertical currents because its temperature decreases by 5-1/2°F. per 1,000 feet of elevation. Such air is stirred by vertical currents so that the temperature and humidity are the same horizontally at the same elevation. This is indicated by the flat bases of the cumulus clouds, the 100-percent humidity level being at the same elevation throughout the picture.

Slide 19 This is an example of unstable air. Vertical motion is demonstrated by two dust devils of a rather potent size and the dissipating stages of an ice-top cumulus that apparently did not quite reach cumulonimbus size.

Slide 20 Stable air has a different set of indicators. There is an obvious absence of bertical mixing and a tendency for horizontal layers. Temperature decreases less rapidly with elevation. The ultimate in stable air is the inversion--a layer through which the temperature actually increases with elevation.

Slides 1 2 — Along the coast, we often find cool air beneath warm air. This coastal fog is in the cool air over the ocean. Fog, by the way, is cloud in contact with the ground.

Slide 23 — Here is morning stratus in the Willamette Valley. Indicators of stable air in the valleys do not necessarily mean stable air over the mountains, however, since the Cascades often extend well above the cool marine layer.

Slide 24 — Now let us examine clouds associated with thunderstorms. These represent the stages of thunderstorm development. The arrows indicate that motion within the clouds is vertical.

The first stage is the towering cumulus in which all flow is up. These clouds have the solid, sharp-edged cauliflower appearance.

The second stage is the mature, fully active thunderstorm. The top has ascended far above the freezing level and is composed of ice-crystals, giving it a fibrous, more diffuse texture. Precipitation and lightning usually do not occur until this stage is reached. Down drafts are now present associated with the precipitation.

In the final stage, the up currents have disappeared, the entire cloud above the freezing level is turning to snow, and this particular cell will gradually precipitate its moisture and drift apart. The top drifts away in the upper winds in the characteristic anvil shape.

What makes a thunderstorm go? First, there must be a rising current of moist air. This may be initiated by intense heating at the ground, by lifting over a mountain range, or by the wedge action of cooler air as along a cold front.

Slide (cu) 25 — If the lifting continues until the air has cooled to the point of saturation, condensation will occur and a small cumulus cloud will appear. At this point, new energy is pumped into the system by liberation of heat of condensation as water vapor condenses into droplets.

Slide (swel. cu and cb.) 26 — If surrounding air temperature permits, the cloud top continues to rise, cooling by expansion, hence condensing more water vapor and liberating more heat of condensation. The resulting towering cumulus on the left is the first stage of thunderstorm development.

Change from liquid to the ice stage liberates additional heat energy. The result is a rising, cloud column that may penetrate all the way to the stratosphere. As the cloud top changes to snow, it takes on the characteristic anvil shape seen on the right. At any level, temperature of the air through which it rises must always be cooler or the rise will stop.

Slide 7 As the precipitation falls, it cools the air through which it falls by conduction. Falling into unsaturated air below the cloud, the precipitation is further cooled by evaporation, and it continues to cool the air through which it falls. Net result is a cold downdraft beneath the storm. This spreads out ahead of the rain area and is called the thundersquall. It may blow over 30 m.p.h. for several minutes. Such winds radiate out from the rain area without regard to slope of terrain. The winds may be present even though all the precipitation evaporates before it reaches the ground. Where precipitation does reach the ground, the higher the cloud base, the greater the evaporative cooling, and the stronger the wind.

Slide 27 (cont.) Thundersquall winds may result from cumulonimbus type clouds that do not produce lightning. Consequently, when these clouds are present, watch out for strong winds from the direction of the nearest storms.

Slide 28 Now, looking at the indicators of thunderstorm formation, these are small cumulus of fair weather. They indicate that the rising thermals of surface heated air have reached the condensation level. At this point, it looks as though further growth will occur with additional heating, since one higher cloud tower already has formed near the center of the picture.

Slide 29 A cumulus convection cell is similar to the convective circulation over a fire. Both are columns of rising air. Cumulus convective cells sometimes move along with the wind. If a fire convection column combines with a cumulus convection cell, the convective circulation of the fire may be markedly intensified. Similar convection cells may be present in dry air forming no clouds; these are called thermals and are familiar to glider pilots and soaring birds.

Slide 30 The absence of cumulus over the river demonstrates the importance of surface heating in the formation of cumulus clouds.

Slide 31 These altocumulus castellanus indicate conditions favorable for cumulus cell growth at the higher, middle cloud layer. Coupled with sufficient heating at the ground, thunderstorms could develop. This type of cloud is a thunderstorm indicator. Often seen in the morning or evening, it may be followed by thunderstorms within 36 hours 60 to 80 percent of the time in some parts of the country. Thunderstorms are most likely in the particular mass of air in which these clouds appear, but they may have moved a long way in 36 hours. Note the definite vertical development. Thunderstorms occasionally build from this middle cloud level.

Slide 32 These are swelling cumulus and have reached the first stage of thunderstorm development. Note the hard cauliflower appearance. The little cloud in the upper left is fracto cumulus.

Slide 33 Here is a mature thunderstorm. The top is changing to ice crystals and has just begun to fan out in anvil shape. Precipitation will soon appear below the cloud.

Slide — The same cloud a few minutes later shows greater development of the ice top anvil.

Slide 35 — In another few minutes, rain began falling beneath the cloud and the anvil has taken on a smoother fibrous texture indicating snow structure.

Slide 36 — This is another fully developed cumulonimbus with the characteristic anvil. It is in the final or dissipating stage. This does not mean the storm is over, however, since new cumulus cells usually form, and the new cells go through the cycle which usually takes about 30 minutes.

Slide 37 — Immediately beneath the cumulonimbus there may be a heavy shower. If cloud bases are high, this may not reach the ground and we would call it a dry thunderstorm.

Slide 38 — Downrushing cold air will spread out from the shower area as a thundersquall wind. The wind is likely to extend a mile or so beyond the rain area. The wind may occur even if the precipitation does not reach the ground.

Slide 39 — Lightning may also be expected. If seen from a distance greater than the thunder can be heard, it may be called heat lightning. Thunder can usually be heard for 15 miles. Heat lightning usually refers to the reflection in the sky from the distant lightning flashes in thunderstorms. Lightning almost never occurs without a thunderstorm. Sheet lightning is the illumination of the cloud from lightning occuring within the storm.

Slide 40 — This represents an average thunderstorm for the northern Rocky Mountains. It produces about 100 lightning discharges, 40 percent of which are cloud to ground. The higher the top, the greater the number of discharges.

Slide 41 — Cold air spreading outward from beneath a large thunderstorm may set off additional storms as it advances. This diagram shows thunderstorms building along the cold air edge forming what amounts to a squall line. Though such a squall line may grow to 50 miles in length and advance at 20 to 40 m.p.h. for as long as 6 hours, it will usually be too small to appear on any weather map or to be included in the routine area forecast. You'll have to see it coming.

Slide 42 — Thunderstorms may occur singly, scattered along mountain ranges, or in lines along cold fronts or squall lines. This is a squall line as viewed from the air, and is a solid line of thunderstorms. Anvil tops from mature cells are mostly obscured by the younger cells.

Slide 43 This is how an eastern Oregon squall line appeared from the surface. It moved along at 40 miles an hour accompanied by even stronger winds and produced considerable lightning and an inch of rain. It is moving toward the camera. The low cloud base indicates considerable moisture in the air mass, hence the possibility of heavy precipitation.

Slide 44 The same squall line looked like this an hour or so later as it approached Bend.

Slide 45 The most intensive study of Oregon and Washington thunderstorms was done by W. G. Morris of the Experiment Station some years ago, but the results are still valid. Every thunderstorm over the National Forests was meticulously reported and charted over a 7-year period. This map shows the actual tracks of all storms during one summer. In the 7 years, no "breeding areas" were evident.

Seventy percent of the thunderstorms in western and central Oregon moved from a southerly direction, that is from somewhere between southwest and southeast. Northeast Oregon storms moved predominantly from the southwest; and Washington storms moved from any direction except northeast and east.

Slide 46 Thunderstorms cannot usually be predicted with certainty. General conditions favorable for their development can usually be forecast, but the time and place must be left for the observer to determine. This should not be difficult because the signs are usually plentiful if you read them. When clouds like these show up in the distance, keep an eye on them.

Slide 47 Now, we are going to talk about clouds that indicate wind conditions that may be important to fire behavior. These are the standing wave clouds or lenticular altocumulus. The clouds stay in one place while the wind blows through them. They form on one edge and dissipate on the other. They indicate a vertical wave pattern that may or may not be reflected at the surface. These motions are mechanical; they do not depend on condensation for energy and may be present in the same form in dry, cloudless air.

Slide 48 The best known work with the mountain wave has been done in the Owen's Valley in California. This shows three levels of cloud in the wave. The lowest is called a rotor cloud, the middle is the typical lenticular cloud, and the highest a cirrus cap.

Slide 49 This is the flow pattern that produced the clouds in the preceding slide. Note the surface winds. There is a calm area between surface winds from opposite directions. A fire in the calm area beneath rising currents would produce a very active convective system. On the other side of the rotor, descending air would inhibit convection, but might produce quite erratic surface winds and fire spread.

Slide 50

This is another standing wave in the Owen's Valley. Note how the dust is blown along the surface for some distance before being lifted into the rotor cloud.

Slide 51

Standing waves are formed frequently by the low Tualatin Mountains that make up Portland's west hills. Often the waves remain aloft and apparently do not affect surface winds. The wave clouds in this slide were over the Willamette Valley in waves formed by east winds blowing over the Cascades.

Slide 52

This fearsome wave cloud appeared in New Zealand. Since the rotor cloud is distinctly present at a low elevation, we would expect that surface winds were typically affected.

Slide 53

The specific wave pattern depends on the height of the ridge, the velocities of the winds across the ridge, the stability of the air, and the presence of other ridges. This slide shows several possible types of airflow across a ridge. Arrows at the left indicate relative windspeeds at various heights. Note the different wave lengths and different wave heights. You can see that with generally rough terrain, it is likely that some amazing wind patterns can be produced under conditions favoring the formation of the standing wave cloud. Remember, however, the cloud does not enter into this process. The same motions can be present without the cloud if the temperature and wind structure are the same and the air mass dry. But, when the signboard is there, be sure you read it.

Slide 54

Last, we will look at clouds indicative of approaching low pressure storm systems. An approaching low may be important because of the precipitation it may bring, but a low may also be preceded by considerable wind even if no rain occurs. These next clouds are not as important by themselves as is the evolution from one cloud type to another. These typical cirrus mean nothing by themselves, but if they gradually develop into a thin cirrostratus overcast, this is often significant.

Slide 55

Cirrostratus is the cloud in which halos form around the sun and moon. In many areas, cirrostratus indicates better than a 50-percent chance of rain within 36 hours.

Slide 56

If middle clouds form beneath or following the cirrostratus, this indicates a deepening, lowering layer of moist air and the probable approach of a low pressure storm system. The low may produce rain, but it is also likely to produce increasing and changing winds.

Slide 57

Or, the cirrostratus may gradually thicken and lower to become altostratus. The sun's disk becomes obscured though its position is indicated by a bright spot. When thickening completely obscures the sun, the cloud is called nimbostratus. Steady rain often comes from this type of cloud though it is often obscured by lower clouds, such as fractostratus, that are formed by the precipitation.

Slide 8 Clouds are also useful for coloring sunrises and sunsets.

(Go directly into cloud motion movie. Same picture introduces movie.)

(At conclusion of movie, turn on tape-slide apparatus again.)

Now you know all about clouds. Sometimes it is suggested to the forecaster that he should look out the window before he issues his forecast. This is a very sensible suggestion because he can obtain much up-to-date information from the clouds. He may not be able to see the clouds over your station or your fire, however, but you can. So you have a potential advantage over the forecaster whenever there are signboards available advertising the current and expected weather.

In the remaining time, let us practice on what we have learned.

A You are at a fire. This is the way the sky looks. You are particularly concerned with surface winds for burning-out this afternoon and evening, and about any prospect for rain. Mr.------, what do these clouds indicate?

Answer: The standing wave clouds indicate wave motions that could influence surface wind patterns. There may be zones where stronger upper winds reach the surface, other zones where the wind seems to skip or even reverse direction. Smoke column behavior should be watched for effects of predominant downward or upward flow.

The cirrus do not indicate anything unless they increase and are replaced by lower cloud types.

B At 10 o'clock we have this sky. The cirrus cloud seems to be from the south. Mr.------, for what conditions should the fire-weather security watch be particularly alert? How can you tell?

Answer: The dense cirrus is probably an old anvil top. Thunderstorm might develop in the same airmass again. They would probably move from the south; a favorable direction for thunderstorm formation. The cumulus of fair weather show that moisture is present in lower layers. With 5 hours of warming still remaining, thunderstorms are a distinct possibility.

C A few scattered cirrus at noon have changed to this sky at 3 p.m. Mr.------, what are these clouds and what do they indicate? What should we watch for during the next few hours?

Answer: These are cirrostratus and possibly precede a larger cloud system associated with a low pressure center. If the clouds continue to thicken and particularly if the cloud form changes to lower types, the approach of a low is more certain.

D An hour after the preceding slide, the sky had this appearance. The clouds are from the southwest. Mr.------, what is this indicating to you?

Answer: This is a sheet of altocumulus. The clouds have lowered in the past hour and the approach of a low pressure system with accompanying wind changes and possible rain becomes more certain.

E At sunrise next morning, we see this with clouds from the south. Mr. -------, can you tell us what has happened to the atmosphere and what weather events may be expected?

Answer: These altocumulus appear lower than the altocumulus of the previous afternoon, but the cirrus have disappeared and there is considerably more blue sky, hence the airmass is drier. The threat of rain has diminished. These altocumulus have very little vertical development, hence are not thunderstorm indicators.

F By late afternoon, we have these clouds from the SSE. Mr.-----, how would you report them, and are they of any importance?

Answer: These altocumulus castellanus clouds indicate moisture and instability at their level and a possibility of thunderstorm within 36 hours. They differ from the altocumulus of the preceding slide in their vertical development.

G By noon the following day, we have these clouds. Mr.------, what weather conditions should we expect during the afternoon?

Answer: These swelling cumulus have about reached thunderstorm size. Thunderstorms should be expected with attendant thundersquall winds spreading outward from beneath each storm. With high cloud bases, strong winds are likely and precipitation at ground level may be light. All fire forces should be alerted to the possibility of thundersquall winds.

H A little later the same afternoon, a lookout in the weather security net saw this formation approaching. Mr.------, should he report, what should he report, and why?

Answer: This appears to be a line of falling precipitation or virga. Since earlier clouds indicated thunderstorms, this may be a squall line. It is likely to be accompanied by strong gusts, especially since cloud bases are high. It should be reported to the fire headquarters as an approaching weak squall line. His first report would be followed up by a report of wind intensity when accompanying wind has been observed.

I If that lookout had seen this approaching rapidly from the southeast, what should he have reported, Mr.------?

Answer: This is an intense squall line. At this distance, thunder would be heard and its approach would be evident. This squall was accompanied by 40-50 mile per hour winds, and, as indicated by the low cloud base, considerable rain.

Late in the afternoon, you could see this from the fire. Mr.------, what is indicated?

Answer: The anvil from a thunderstorm is apparently moving overhead. Since the anvil precedes the thunderstorm, we would expect that the storm is moving toward the fire and would alert personnel to the possibility of thundersquall winds.

About the same time as the previous slide, one of the security net observers saw this. Mr.-------, what is it, and is it important? Why?

Answer: These mamma characteristically form on the under side of the anvil top. This means that a thunderstorm is only a few miles away.

SLIDES USED WITH SLIDE-TAPE CLOUD LECTURE (cont'd.)

1.	Aerial of cumulonimbus and associated clouds	OPC 11
2.	Montana altocumulus floccus (good a. castellanus slide needed)	D 21
3.	Cumulonimbus over Ochoco	OPC 6
4.	Wave cloud in lee of Mt. Hood from Parkdale	OPC 18
5.	Old anvil top cirrus	OPC 7
6.	Aerial of stratus with Mt. Hood	OPC 15
7.	Swelling cumulus over mountain range	D 4
8.	Cirrus at sunset	OPC 10
9.	Spreading anvil top over Reed College	OPC 22
10.	Precipitation reaching ground	D 12
11.	Altocumulus	D 22
12.	Fractocumulus with fair weather cumulus near Dixie Bu.	OPC 12
13.	Montana altocumulus castellanus	D 27
14.	Mamma from beneath anvil top	OPC 19
15.	Virga	D 10
16.	Lenticular altocumulus	OPC 1
17.	Drawing of cloud families (Meteorology for Naval Aviators)	Navy
18.	Indicators of instability (USFS PNW Res. Paper 43)	
19.	Dust devils and glaciating cumulus	OPC 14
20.	Indicators of stability (USFS PNW Res. Paper 43)	
21.	Fog below Otter Crest	OPC 15
22.	Fog and stratus in Willamette Valley from Goat Mtn.	Moltzau
23.	Three states of thunderstorm development (AF Manual 105-5, Fig. 12-7)	
24.	Cumulus of fair weather	D 1
25.	Swelling cumulus and cumulonimbus	D 32
26.	Diagram of thunderstorm winds (CAA Tech Manual No. 104, p.63)	
27.	Growing fair weather cumulus	D 2
28.	Diagram of convective systems (Fire Control Notes, April 1954)	
29.	Absence of cumulus over Columbia River	OPC 6
30.	Montana altocumulus castellanus	D 26
31.	Towering cumulus beginning to glaciate	D 3
32.	Cumulonimbus with anvil beginning to form	D 6
33.	Same as preceding slide but 6 min, later	D 7
34.	Ditto, another 6 min. later	D 8
35.	Cumulonimbus with well-developed anvil	D 11
36.	Shower below cumulonimbus	D 15
37.	Blowing trees	OPC 11
38.	Lightning	OPC 14
39.	Typical northern Rocky Mtn. thunderstorm diagram (Proj. Skyfire in Weatherwise Aug 1962)	
40.	Thunderstorm mesosystem diagram (Final Rept. Mesomet. Study of Selected Areas in the U.S., Univ. of Chicago, Sponsored by U.S. Signal Corps.)	

41.	Squall line over Texas panhandle from air	OPC	14
42.	Squall line from Brothers, Oregon	OPC	16
43.	Same Squall line as #42 as it approached Bend	OPC	20
44.	Map of thunderstorm tracks in Oregon and Washington in 1930 (from Morris, PNW publication 1934) PNW Forest & Range Expt. Sta.)		
45.	Swelling cu and cb near Enterprise	OPC	10
46.	Lenticular altocumulus	D	25
47.	Bishop wave by Betsy Woodward in Cloud Study by Ludlam and Scorer		
48.	Diagram of flow shown in #47		
49.	Bishop wave from aloft (copy--appears on cover of Weather and elsewhere Also plate 161 Vol. II International Cloud Atlas)		
50.	Lenticular altocumulus from Council Crest	OPC	23
51.	Lenticular altocumulus in New Zealand (copy from Weather)		
52.	Diagram of vertical wave patterns in lee of ridge (copy from Scorer article)		
53.	Cirrus	OPC	12
54.	Thickening cirrostratus	OPC	1
55.	Altocumulus over Tualatin Mtns.	OPC	21
56.	Altostratus or nimbostratus	OPC	15
57.	Sunrise from Custom House	OPC	3

Supplementary discussion clouds;

A.	Lenticular altocumulus and scattered cirrus.	D	33
B.	Cumulus humilis and a dense cirrus	D	31
C.	Thick cirrostratus	OPC	19
D.	Altocumulus overcast with dissipation trail and some cirrus	OPC	17
E.	Altocumulus	D	20
F.	Altocumulus castellanus	OPC	10
G.	Towering cumulus glaciating and some dissipating	OPC	5
H.	Line of Virga	D	14
I.	Eastern Oregon squall line	OPC	17
J.	Anvil top overhead and distant small cumulonimbus	OPC	10
K.	Mamma beneath anvil top	OPC	20

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INSTRUCTOR'S LESSON PLAN

SUBJECT: Int. Fire Behavior
INSTRUCTOR: Bob Miller
TITLE OF LESSON: Winds & Topography
FILE NO. 5120
DATE: 3/17/71
LENGTH OF LESSON: 55 Minutes
NO. ASSISTANTS:
METHOD OF INSTRUCTION:
PLACE: Rocky Mtn. F. & R.E.S.
TRAINING AIDS: Vu-Graph, Screen
NUMBER IN AUDIENCE:
OBJECTIVE:

TIME	LESSON OUTLINE	AIDS & CUES
1300	1. INTRODUCTION.	

FOR THE NEXT HOUR WE ARE GOING TO TALK ABOUT WIND AND HOW TOPOGRAPHY AFFECTS IT.

WIND IS THE MOVEMENT OF AIR OVER THE EARTH'S SURFACE. WIND IS OF MAJOR IMPORTANCE IN FIRE BEHAVIOR AND CONTROL. WINDS SPEED UP THE DRYING OF FOREST FUELS BY CARRYING AWAY MOISTURE LADEN AIR. LIGHT WINDS AID A FIREBRAND IN IGNITING A FIRE. ONCE A FIRE IS STARTED, WIND INTENSIFIES COMBUSTION BY FEEDING IT OXYGEN. WIND INCREASES FIRE SPREAD BY CARRYING HEAT AND BURNING EMBERS TO NEW FUELS. IT MAKES RADIATION MORE EFFECTIVE IN PREHEATING AND IGNITING THE FUEL AHEAD OF THE FIRE BY BENDING THE FLAMES AND BRINGING THEM CLOSER TO THE FUEL. EXTREME FIRE BEHAVIOR DOES NOT USUALLY OCCUR WHEN WIND CONDITIONS ARE UNFAVORABLE FOR RAPID COMBUSTION, REGARDLESS OF THE

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TIME	LESSON OUTLINE	AIDS & CUES
	FUELS PRESENT AND TOPOGRAPHY OF THE AREA.	
	NOT ONLY DOES WIND AFFECT THE FIRE, BUT THE FIRE MAY AFFECT THE WIND. THE FIRE MAY MODIFY WIND FLOW CHARACTERISTICS AND BEHAVIOR. A KNOWLEDGE OF WIND AND ITS INTERRELATIONSHIPS WITH FIRE IS ESSENTIAL FOR ANTICIPATING OCCURRENCE AND BEHAVIOR OF FIRES AND FOR BRINGING FIRES UNDER CONTROL.	
	2. <u>MEASURING WIND</u>.	
	<u>DIRECTION</u>. WIND IS DESCRIBED IN TERMS OF DIRECTION AND SPEED. THE DIRECTION OF WIND IS THE DIRECTION <u>FROM</u> WHICH IT IS BLOWING. A NORTH WIND BLOWS FROM THE NORTH. A NORTHEAST WIND FROM THE NORTHEAST.	
	<u>WIND SPEED</u>. WIND SPEED IS USUALLY MEASURED IN EITHER MILES PER HOUR OR KNOTS, WITH ROTARY CUP ANEMOMETERS.	
1305	3. <u>WHY AND HOW THE WIND BLOWS</u>.	
	THERE ARE TWO BASIC KINDS OF WIND:	

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TIME	LESSON OUTLINE	AIDS & CUES
	1. GRADIENT WINDS. THESE ARE WINDS BLOWING FROM A HIGH PRESSURE AREA TO A LOW PRESSURE AREA.	
	2. CONVECTIVE WINDS. WINDS CAUSED BY UNEVEN HEATING OF THE EARTH'S SURFACE IN A LOCAL AREA.	VU - GRAPH #1
	GRADIENT WINDS MOVE IN A HORIZONTAL DIRECTION BECAUSE OF PRESSURE DIFFERENCES. CONVECTIVE WINDS MOVE IN A VERTICAL DIRECTION BECAUSE OF BUOYANT FORCE. ALL AIR MOVEMENT (WIND) IS CAUSED BY TEMPERATURE DIFFERENCES.	
	1. GRADIENT WINDS.	
	WE HAVE SEEN EARLIER IN THE COURSE THAT CENTERS OF HIGH AND LOW PRESSURE FORM AS THE RESULT OF VARIOUS INFLUENCES, AND THAT THE RESULTING PRESSURE GRADIENT FROM HIGH PRESSURE TO LOW PRESSURE IS ONE OF THE SEVERAL FORCES OPERATING TO MOVE AIR OVER THE EARTH'S SURFACE. OTHER FORCES ARE THE DEFLECTION FORCE DUE TO THE ROTATION OF THE EARTH (CORIOLIS FORCE), THE	

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	CENTRIFUGAL FORCE AS THE AIR MOVES IN A CURVED PATH, AND FRICTIONAL FORCE, DUE TO FRICTION AT THE EARTH'S SURFACE, WHICH SLOWS THE WIND AND CAUSES IT TO BLOW AT AN ANGLE ACROSS THE ISOBARS FROM HIGH TO LOW PRESSURE.	
	THE FRICTIONAL FORCE VARIES WITH THE ROUGHNESS OF THE EARTH'S SURFACE. IT IS LEAST OVER WATER AND GREATEST OVER ROUGH TOPOGRAPHY. THE DEPTH OF THE AIR LAYER THROUGH WHICH THE FRICTIONAL FORCE IS EFFECTIVE ALSO VARIES WITH THE ROUGHNESS OF THE SURFACE. IT IS SHALLOWER OVER SMOOTH SURFACES SUCH AS WATER AND DEEPER OVER ROUGH TOPOGRAPHY. THE DEPTH MAY ALSO VARY WITH THE STABILITY OF THE LOWER ATMOSPHERE. A LOW INVERSION WILL CONFINE THE FRICTIONAL EFFECT TO A SHALLOW LAYER, BUT A DEEP LAYER CAN BE AFFECTED WHEN THE AIR IS RELATIVELY UNSTABLE. USUALLY THE FRICTION LAYER IS CONSIDERED TO BE 1500 TO 2000 FEET IN DEPTH.	
	ABOVE THE FRICTION LAYER, IF THE PRESSURE GRADIENT IS NOT CHANGING RAPIDLY, THE WIND BLOWS PARALLEL TO THE ISOBARS. THE PRESSURE GRADIENT, CENTRIFUGAL,	

TIME	LESSON OUTLINE	AIDS & CUES
	AND CORIOLIS FORCES ARE IN BALANCE. THIS WIND IS KNOWN AS THE GRADIENT WIND. ONE CAN COMPUTE THE GRADIENT WIND FROM THE WEATHER MAP. THE SPACING OF THE ISOBARS IS A MEASURE OF THE PRESSURE GRADIENT. THE CLOSER THE ISOBARS, THE STRONGER THE PRESSURE GRADIENT.	
	THE EFFECTS OF THE GRADIENT WIND ON LOCAL SURFACE WIND PATTERNS ARE NOT SIMPLE. WE CAN MAKE SEVERAL GENERAL STATEMENTS, HOWEVER. THE EFFECT OF THE GRADIENT WIND WILL BE GREATER WITH STRONGER GRADIENT WINDS. IN FACT, STRONG GRADIENT WINDS CAN COMPLETELY OBLITERATE LOCAL WIND PATTERNS. THE GRADIENT WIND EFFECT WILL VARY WITH THE STABILITY OF THE LOWER ATMOSPHERE. STABLE LAYERS, OF WHICH INVERSIONS ARE AN EXTREME TYPE, TEND TO "INSULATE' THE LOCAL WIND PATTERNS FROM THE GRADIENT WIND AND THUS MINIMIZE ITS EFFECT. WHEN THE LOWER ATMOSPHERE IS REALATIVELY UNSTABLE THERE IS MORE INTERCHANGE BETWEEN THE GRADIENT LEVEL AND THE SURFACE LAYER, AND THE GRADIENT WIND EFFECTS ARE GREATER. THIS MEANS THAT THE GRADIENT WIND EFFECTS WILL HAVE A	VU-GRAPH #2

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TIME	LESSON OUTLINE	AIDS & CUES
	DIURNAL VARIATION ALSO, BEING GREATEST DURING THE DAYTIME WHEN THE LOWER ATMOSPHERE IS REALATIVELY UNSTABLE AND LEAST AT NIGHT WHEN IT IS MORE STABLE. CERTAIN LOCAL WIND PATTERNS MAY BE LESS AFFECTED BY THE GRADIENT WIND THAN OTHERS BECAUSE OF THE TYPE OF TOPOGRAPHY IN WHICH THEY OCCUR. FOR EXAMPLE, THE RIDGES AT THE SIDES AND HEAD OF A VALLEY WILL PROTECT THE LOCAL WIND PATTERN IN THE VALLEY FROM THE GRADIENT WIND. THE STEEPER AND HIGHER THESE RIDGES ARE, THE GREATER THE PROTECTION THEY OFFER.	
1310	A.) <u>TURBULENCE</u>. WINDS VARY CONSIDERABLY IN BOTH DIRECTION AND SPEED OVER SHORT INTERVALS OF TIME. THE RAPIDITY OF FLUCTUATIONS IN DIRECTION INCREASE AS WIND SPEED INCREASES ALTHOUGH THE AMOUNT OF THE VARIATION TENDS TO BECOME LESS. WIND SPEED IS SELDOM STEADY BUT BLOWS IN A SERIES OF GUSTS AND LULLS. THIS IRREGULAR MOTION OF THE AIR IS KNOWN AS TURBULENCE. THE TWO PRINCIPAL CAUSES OF TURBULENCE NEAR THE EARTH'S SURFACE ARE ATMOSPHERIC INSTABILITY AND ROUGH TOPOGRAPHY.	

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TIME	LESSON OUTLINE	AIDS & CUES
	WHEN THE LOWER LAYER OF THE ATMOSPHERE IS UNSTABLE, IT OFFERS LITTLE RESISTANCE TO THE TRANSFER OF MOMENTUM EITHER UPWARD OR DOWNWARD. THE USUALLY STRONGER WINDS ALOFT CAN BE BROUGHT DOWN TO THE SURFACE IN GUSTS. LARGER ROLLING EDDIES FORM AND CAUSE FREQUENT CHANGES IN THE SPEED AND DIRECTION OF THE SURFACE WINDS. NORMALLY THIS TYPE OF TURBULENCE IS MOST PRONOUNCED IN THE AFTERNOON WHEN SURFACE HEATING HAS MADE THE LOWER LAYER OF THE AIR UNSTABLE. IT CAN ALSO OCCUR NEAR A DEEP STORM CENTER AT ANY TIME OF THE DAY, FOR THEN A DEEP LAYER OF THE ATMOSPHERE IS USUALLY RELATIVELY UNSTABLE.	
	STRONG WINDS, BLOWING BECAUSE OF A STRONG PRESSURE GRADIENT, CAN BECOME TURBULENT MECHANICALLY IN PASSING OVER ROUGH TOPOGRAPHY EVEN THOUGH THE THERMAL STRUCTURE OF THE AIR IS NOT PARTICULARLY FAVORABLE FOR TURBULENCE. AT STRONG SPEEDS THE AIR WILL "TUMBLE" OVER AND AROUND HILLS AND RIDGES, STRUCTURES AND TREES, PRODUCING VERTICAL AND HORIZONTAL EDDIES SIMILAR TO WATER FLOWING OVER AND AROUND ROCKS IN A STREAM.	

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	LAMINAR AIR FLOW, AS OPPOSED TO TURBULENT FLOW, PRODUCES WINDS THAT ARE MORE STEADY IN BOTH DIRECTION AND SPEED. IT OCCURS WHEN THE LAYER OF AIR NEXT TO THE SURFACE IS STABLE. A NIGHT-TIME SURFACE INVERSION, FOR EXAMPLE, WILL PROTECT THE AIR NEAR THE GROUND FROM THE INFLUENCE OF THE WIND FLOW HIGHER UP. THE COOLER AIR NEAR THE SURFACE FLOWS SMOOTHLY ALONG, FOLLOWING THE TOPOGRAPHY, VARYING LITTLE IN SPEED AND DIRECTION. THIS TYPE OF FLOW IS MOST COMMON DURING THE NIGHT AND EARLY MORNING HOURS BECAUSE OF THE STABLE STRUCTURE OF THE AIR DURING THAT PORTION OF THE DAY.	VU-GRAPH #2 AGAIN
1315	B. <u>LOCAL WINDS RELATED TO LARGE SCALE PRESSURE PATTERNS</u>.	
	B.) <u>FOEHN WINDS</u>. IN MOST MOUNTAINOUS AREAS LOCAL WINDS ARE OBSERVED THAT BLOW OVER THE RIDGES AND DESCEND THE MOUNTAIN SLOPES ON THE LEEWARD SIDE. THESE WINDS ARE CHARACTERIZED BY THEIR WARMTH AND DRYNESS. AT TIMES THEY MAY REACH WHOLE GALE FORCE AND THEY ARE GENERALLY GUSTY. IN FORESTED OR BRUSH-COVERED AREAS	

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TIME	LESSON OUTLINE	AIDS & CUES
	THEY CREATE A CRITICAL FIRE CONDITION. THESE WINDS HAVE COME TO BE KNOWN BY DIFFERENT NAMES IN VARIOUS PARTS OF THE WORLD, AND EVEN IN DIFFERENT PARTS OF THE UNITED STATES. WE SHALL APPLY THE TERM FOEHN TO THIS CLASS OF WIND.	
	THE FOEHN WIND APPEARS WHEREVER THE PREVAILING WIND PASSES OVER A MOUNTAIN BARRIER. AS THE AIR ASCENDS THE WINDWARD SIDE OF THE MOUNTAIN RANGES IT IS COOLED UNTIL THE CONDENSATION LEVEL IS REACHED. CLOUDS THEN FORM AND PRECIPITATION IS PRODUCED, THUS DECREASING THE AMOUNT OF WATER VAPOR IN THE AIR. AS IT DESCENDS THE LEEWARD SIDE OF THE MOUNTAIN RANGE, THE AIR IS WARMED ADIABATICALLY AND IT ARRIVES AT LOWER ELEVATIONS BOTH WARMER AND DRIER THAN IT WAS AT CORRECPONDING LEVELS ON THE WINDWARD SIDE.	
	WHEN A COLD HIGH PRESSURE AREA MOVES INTO THE GREAT BASIN AND STAGNATES THERE, A PRESSURE PATTERN FAVORABLE FOR CHINOOK WINDS ALONG THE EASTERN SLOPES OF THE NORTHERN AND CENTRAL ROCKIES, MONO WINDS ALONG THE WESTERN SLOPES OF THE SIERRA NEVADA, AND SANTA ANA WINDS ON THE	VU-GRAPH #3

TIME	LESSON OUTLINE	AIDS & CUES
	COASTAL SIDES OF THE COAST RANGES OF SOUTHERN CALIFORNIA IS ESTABLISHED. ALL OF THESE ARE FOEHN-TYPE WINDS THAT HAVE COME TO BE KNOWN BY DIFFERENT NAMES IN THESE DIFFERENT AREAS. THE CHINOOK WIND ON THE EASTERN SLOPES OF THE ROCKIES MAY REPLACE COLD CONTINENTAL AIR THAT HAS MOVED INTO GREAT PLAINS FROM CANADA. THIS RESULTS IN VERY ABRUPT TEMPERATURE AND HUMIDITY CHANGES, AND IN THE WINTERTIME WILL CAUSE SNOW TO BE QUICKLY EVAPORATED. THE CHINOOK WIND DOES NOT ALWAYS REMAIN CONTINUOUSLY ON THE SURFACE AT LOWER ELEVATIONS. IF THE MECHANISM IS NOT PRESENT TO REMOVE THE COLD CANADIAN AIR, THE WARM CHINOOK WIND MAY OVERRIDE IT AND NOT BE FELT AT THE SURFACE. AT OTHER TIMES THE WARM CHINOOK REACHES THE SURFACE PERIODICALLY CAUSING EXTREME FLUCTUATIONS IN TEMPERATURE AND HUMIDITY. THE CHINOOK CHARACTERISTICS MAY BE INTENSIFIED IF A WARM RIDGE OF HIGH PRESSURE ALOFT MOVES OVER THE GREAT BASIN AREA AND SUBSIDING AIR FROM ALOFT IS BROUGHT DOWN TO THE SURFACE ON THE EASTERN SLOPES OF THE ROCKIES. THE EXTREMELY LOW HUMIDITIES OF	

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TIME	LESSON OUTLINE	AIDS & CUES
	LESS THAN 5% THAT ARE SOMETIMES RECORDED INDICATE THAT THE AIR MUST ORIGINATE AT HIGH LEVELS. HUMIDITIES HAVE DROPPED AS LOW AS 1% IN DENVER. FORTUNATELY, THESE WINDS USUALLY OCCUR WHEN THE BUI IS NOT TOO HIGH ON N.F. LAND, BUT NOT ALWAYS. THEY HAVE BEEN RESPONSIBLE FOR SOME SERIOUS GRASS AND BRUSH FIRES ON THE EASTERN SLOPE OF THE COLORADO ROCKIES. AIR FLOWING WESTWARD OVER THE SOUTHERN SIERRA NEVADA IS WARMED ADIABATICALLY AS IT DECENDS THE WESTERN SLOPES AND IS KNOWN AS THE MONO WIND WHEN IT REACHES LOWER ELEVATIONS. CONTINUING WESTWARD IT CROSSES THE COSTAL RANGES AND IS FURTHER WARMED AND DRIED OUT AS IT FLOWS DOWNWARD TOWARD SEA LEVEL. IN THE COASTAL REGIONS OF SOUTHERN CALIFORNIA THIS WIND IS KNOWN AS THE SANTA ANA. IT'S MILD TEMPERATURE, EXTREMELY LOW RELATIVE HUMIDITIES, BOTH DAY AND NIGHT, ITS HIGH SPEEDS AND GUSTINESS BRINGS SOUTHERN CALIFORNIA ITS WORST FIRE CONDITIONS. SANTA ANA WINDS ARE MOST FREQUENT DURING THE FALL AND EARLY WINTER, FREQUENTLY BEFORE MUCH RAIN HAS FALLEN SINCE THE RAINLESS SUMMER SEASON, AND DURING THE TIME OF THE YEAR	

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TIME	LESSON OUTLINE	AIDS & CUES
	WHEN THE MOISTURE CONTENT OF THE LIVING BRUSH IS LOW. IN COASTAL MOUNTAINS AND THE VALLEYS AND SLOPES ON THE OCEAN SIDES THE EFFECT OF THE SANTA ANA VARIES. A WARM SANTA ANA WILL AFFECT ONLY THE HIGHER ELEVATIONS OF THE COAST RANGES. IT FAILS TO DESCEND VERY FAR DOWN THE LEEWARD SLOPES BUT INSTEAD FLOWS SEAWARD ALOFT, LEAVING LOCAL CIRCULATIONS PREDOMINANT AT LOW LEVELS. A COLD TYPE SANTA ANA WILL BLOW THROUGH THE GAPS AND OVER THE RIDGES AND ALONG THE SURFACE OF SLOPES AND VALLEYS ON THE LEEWARD SIDE. THIS FLOW CONTINUES BOTH DAY AND NIGHT AND COMPLETELY ERASES ANY TENDENCY FOR A SEA BREEZE OR UP-VALLEY WIND THAT MAY BE PRESENT IN THE DAYTIME. AS THE SANTA ANA WEAKENS A DIURNAL CHANGE SETS IN. DURING THE DAYTIME A LIGHT SEA BREEZE MAY BE NOTED ALONG THE COAST WITH LIGHT UP-VALLEY WINDS IN THE COASTAL VALLEYS AND THE SANTA ANA WINDS ARE HELD ALOFT. AFTER SUNSET THE SEA BREEZE STOPS AND A LAND BREEZE BEGINS. IN THE COASTAL VALLEYS A DOWN-VALLEY WIND SETS IN. SINCE THESE WINDS ARE IN THE SAME DIRECTION AS THE SANTA ANA DURING THE EVENING HOURS THE SANTA	VU-GRAPH #4

TIME	LESSON OUTLINE	AIDS & CUES
	ANA WIND COMES DOWN TO THE SURFACE AND COMBINES WITH THESE LOCAL CIRCULATIONS CAUSING VERY STRONG, GUSTY SURFACE WINDS. DURING THE LATE NIGHT HOURS THE AIR IN THE COASTAL VALLEYS MAY BECOME SO COLD THAT AN INVERSION IS FORMED WHICH AGAIN HOLDS THE SANTA ANA WIND ALOFT. AS THE SANTA ANA CONDITION CONTINUES TO WEAKEN, THE LOCAL CIRCULATIONS BECOME RELATIVELY STRONGER AND THE SANTA ANA WIND IS HELD ALOFT BOTH DAY AND NIGHT.	
1325	2) <u>FRONTAL WINDS</u>. THE DIFFERENT KINDS OF FRONTS AND THE WEATHER ASSOCIATED WITH THEM WERE DISCUSSED EARLIER. HERE WE WILL CONSIDER THE CHANGE AND THE CHARACTER OF THE SURFACE WINDS WITH THE PASSAGE OF FRONTS. THE CHANGE IN WIND DIRECTION WITH THE PASSAGE OF A FRONT FREQUENTLY TAKES PLACE VERY SUDDENLY AND THE WINDS MAY BE VERY GUSTY. FOR THESE REASONS FRONTAL WINDS ARE IMPORTANT IN FIRE CONTROL. THE SUDDEN SHIFT IN WIND WILL CHANGE THE DIRECTION AND SPREAD OF A FIRE AND MAY ENDANGER MEN AND EQUIPMENT.	

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TIME	LESSON OUTLINE	AIDS & CUES
	IN THE NORTHERN HEMISPHERE THE SURFACE WIND WILL INVARIABLY SHIFT IN A CLOCKWISE DIRECTION AS A FRONT PASSES.	
	AHEAD OF A WARM FRONT THE SURFACE WIND USUALLY BLOWS FROM A SOUTHEASTERLY OR SOUTHERLY DIRECTION. WITH THE FRONTAL PASSAGE THE WIND GRADUALLY SHIFTS CLOCKWISE FROM 45^{0} TO 90^{0}. THE PASSAGE OF A WARM FRONT IS USUALLY ACCOMPANIED BY STEADY WINDS RATHER THAN GUSTY WINDS SINCE THE LAYER OF AIR NEXT TO THE GROUND IS GENERALLY STABLE.	FIG. 5
	IN CONTRAST TO THE PASSAGE OF A WARM FRONT, THE PASSAGE OF A COLD FRONT IS USUALLY SHARP AND DISTINCT. AHEAD OF THE COLD FRONT THE WIND GENERALLY BLOWS FROM THE SOUTH OR SOUTHWEST. AS THE COLD FRONT APPROACHES THE WINDS INCREASE IN SPEED AND BECOME TURBULENT. IN THE FRONTAL ZONE THERE MAY BE VIOLENT TURBULENCE AND SQUALLY WEATHER, ESPECIALLY IF THUNDERSTORMS ARE PRESENT. AS THE COLD AIR MOVES OVER THE EARTH'S SURFACE, FRICTION WITH THE GROUND TENDS TO RETARD THE SURFACE WIND, WHILE ALOFT THE COLD AIR SURGES	

TIME	LESSON OUTLINE	AIDS & CUES
	AHEAD AND OVERRUNS A LAYER OF WARM AIR. THIS OVERRUNNING PRODUCES EXTREMELY UNSTABLE CONDITIONS AND SQUALLY WEATHER RESULTS. WITH THE FRONTAL PASSAGE THE WIND SHIFTS WEST OR NORTHWEST. THE AMOUNT OF THE SHIFT MAY BE FROM 45^{o} TO AS MUCH AS 180^{o} WITH SLOW MOVING FRONTS. THE COLD AIR MOVES OVER WARMER GROUND AND CONTINUES TO BE RELATIVELY UNSTABLE, SO THAT STRONG GUSTY WINDS MAY CONTINUE FOR SOMETIME AFTER THE FRONTAL PASSAGE.	
	THE WIND SHIFT ACCOMPANYING THE PASSAGE OF AN OCCLUSION IS USUALLY 90^{o} OR MORE. THE WIND GENERALLY SHIFTS FROM A SOUTHERLY DIRECTION TO WESTERLY OR NORTHWESTERLY. IN THE CASE OF A WARM-TYPE OCCLUSION THE WIND SHIFTS IS MORE GRADUAL JUST AS IT IS WITH A WARM FRONT. THE WIND SHIFT WITH A COLD-TYPE OCCLUSION RESEMBLES THAT OF A COLD FRONT EXCEPT THAT THE SQUALLINESS IS ABSENT. SOME GUSTINESS MAY ACCOMPANY THE FRONTAL PASSAGE, HOWEVER, AND CONTINUE TO THE REAR OF THE FRONT IF THE COLD AIR IS UNSTABLE.	VU-GRAPH #6

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TIME	LESSON OUTLINE	AIDS & CUES
	3) MOUNTAIN WAVES. THESE WINDS ARE CAUSED BY MODERATE TO STRONG GRADIENT WINDS IN A STABLE ATMOSPHERE. THEY OFTEN CAUSE STRONG DOWNSLOPE WINDS AND EDDIES ON LEE SLOPES. THEY ALSO CHARACTERISTICALLY CAUSE FORMATION OF LENTICULAR (LENS SHAPED) CLOUDS FROM OROGRAPHIC LIFTING.	VU-GRAPH #6A
1330	2. CONVECTIVE WINDS.	
	A) LAND AND SEA BREEZE. LOCAL WINDS CAUSED BY TEMPERATURE DIFFERENCES BETWEEN THE LAND AND SEA BREEZES--THE WIND BLOWING FROM THE SEA TO LAND BY DAY IS THE SEA BREEZE AND THE WIND THAT BLOWS FROM LAND TO SEA AT NIGHT IS THE LAND BREEZE.	
	WATER AND LAND DIFFER IN HEAT ABSORBING PROPERTIES. MORE HEAT IS REQUIRED TO RAISE THE TEMPERATURE OF A GIVEN AMOUNT OF WATER THAN THE SAME AMOUNT OF LAND. IN ADDITION THE HEAT RECEIVED BY A LAND SURFACE IS CONFINED TO THE TOPMOST LAYER OF GROUND. IN CONTRAST THE SUN'S RAYS PENETRATE MORE DEEPLY INTO THE WATER.	

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TIME	LESSON OUTLINE	AIDS & CUES
	MIXING OF THE WATER ALSO HELPS TO CARRY THE WARMED SURFACE WATER DOWNWARD AND THUS DISTRIBUTES THE HEAT THROUGH A DEEPER LAYER. AS A RESULT THE WATER SURFACE IS NOT HEATED TO AS HIGH A TEMPERATURE DURING THE DAYTIME AS THE ADJACENT LAND SURFACE AND THE AIR OVER THE WATER SURFACE ALSO REMAINS COOLER THAN THAT OVER LAND.	
	DURING THE DAYTIME WHEN THE WARM AIR OVER THE LAND EXPANDS AND BECOMES LESS DENSE THE PRESSURE OVER LAND BECOMES RELATIVELY LOWER THAN THE PRESSURE OVER THE ADJACENT COOL WATER. A HORIZONTAL MOVEMENT OF AIR FROM THE WATER TO THE LAND BEGINS. AS THE WARM AIR OVER THE LAND RISES IT COOLS ADIABATICALLY. PRESSURE ALOFT THEN BECOMES GREATER THAN THAT OVER WATER AND THE AIR ALOFT BEGINS A RETURN FLOW TO THE SEA. SINKING OF THE AIR OVER THE WATER COMPLETES THE SEA BREEZE CIRCULATION.	VU-GRAPH #7
	THE SEA BREEZE HAS A NOTICEABLE EFFECT ON FIRE ACTIVITY. IT USUALLY BRINGS IN AIR THAT REMAINED RELATIVELY COOL OVER THE SEA AND HAS PICKED UP MOISTURE FROM THE WATER SURFACE. THIS MARINE	

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TIME	LESSON OUTLINE	AIDS & CUES
	AIR, WITH ITS LOWER TEMPERATURES AND HIGHER RELATIVE HUMIDITIES, DECREASES THE FIRE ACTIVITY QUICKLY. MANY TIMES IT WILL BRING IN FOG THAT MAKES GOING FIRES "LAY DOWN" AIR IN A SEA BREEZE THAT DEVELOPS AT THE END OF A PERIOD OF OFFSHORE WIND FLOW MAY BE QUITE DRY, HOWEVER, BECAUSE THE RETURNING AIR FROM THE SEA HAS SPENT ONLY A SHORT TIME OVER THE WATER.	
	AT NIGHT THE CIRCULATION IS REVERSED. THE LAND RADIATES ITS SURFACE HEAT MORE QUICKLY INTO SPACE THAN DOES THE WATER. THE LAND BECOMES COOLER THAN THE WATER AND SO DOES THE AIR OVER THE LAND BECOME COOLER THAN THAT OVER THE WATER. AS A RESULT THE PRESSURE BECOMES RELATIVELY HIGHER OVER LAND THAN OVER THE ADJACENT WATER AND A MOVEMENT OF AIR FROM LAND TO WATER BEGINS. THIS OFFSHORE WIND IS KNOWN AS THE <u>LAND BREEZE</u>. ALOFT A RETURN FLOW OF AIR FROM OVER THE WATER TO OVER THE LAND COMPLETES THE NIGHT-TIME CIRCULATION.	VU-GRAPH #7

TIME	LESSON OUTLINE	AIDS & CUES
1335	B) <u>MOUNTAIN & VALLEY WINDS</u>	

MOUNTAIN AND VALLEY WINDS ARE CAUSED BY THE TOPOGRAPHY AND ARE THE RESULT OF LOCAL HEATING AND COOLING. THEY MAY BE DIVIDED INTO TWO DIFFERENT BUT MUTUALLY DEPENDENT WIND SYSTEMS, VALLEY WIND MOVES ALONG THE LONGITUDINAL AXIS OF THE VALLEY. THE DEPTH OF THE VALLEY WIND IS ALMOST THE SAME AS THE HEIGHT OF THE RIDGES ON THE SIDES OF THE VALLEY. THE VALLEY WIND IS CAUSED BY THE TEMPERATURE DIFFERENCE BETWEEN THE AIR IN THE VALLEY AND THE AIR AT THE SAME ELEVATION OVER THE ADJACENT PLAIN OR LARGER VALLEY. SLOPE WINDS ARE SHALLOW WINDS ON THE SLOPES FORMING THE SIDES OF THE VALLEY. <u>THEY BLOW UP SLOPE BY DAY AND DOWN SLOPE BY NIGHT</u>. THESE WINDS ARE CAUSED BY THE DIFFERENCE IN TEMPERATURE BETWEEN THE AIR NEAR THE SLOPE AND THE AIR AT THE SAME ELEVATION ABOVE THE VALLEY FLOOR. SLOPE WINDS ALSO OCCUR ON THE SLOPES OF ANY HILLS, MOUNTAINS, OR RIDGES. ABOVE THE SLOPE AND VALLEY WIND SYSTEMS IS THE PREVAILING GRADIENT WIND.

AS WITH LAND AND SEA BREEZES, SLOPE AND VALLEY

TIME	LESSON OUTLINE	AIDS & CUES
	WINDS ARE BEST DEVELOPED WHEN SKIES ARE CLEAR AND GRADIENT WINDS ARE LIGHT.	
	THE TEMPERATURE DIFFERENCE, AND THEREFORE THE PRESSURE DIFFERENCE REVERSES FROM DAY TO NIGHT. DURING THE DAYTIME THE AIR IN THE VALLEY BECOMES WARMER THAN THE AIR AT THE SAME LEVEL OVER THE ADJACENT PLAIN OR VALLEY. THE WARMER AIR IS LESS DENSE AND THEREFORE THE PRESSURE AT THE FLOOR OF THE VALLEY IS LESS THAN AT THE SAME ELEVATION OVER THE PLAIN. THE RESULTING LOCAL PRESSURE GRADIENT, DIRECTED FROM THE PLAIN TO THE VALLEY CAUSES AIR TO FLOW INTO THE VALLEY AS AN UP-VALLEY WIND. AT SOME HEIGHT ABOVE THE VALLEY A RETURN FLOW CARRIES AIR TOWARD THE PLAIN. THERE ARE SEVERAL REASONS FOR THIS DIFFERENTIAL HEATING. FIRST, THE SAME AMOUNT OF HEAT FROM THE SUN IS USED TO HEAT A SMALLER VOLUME OF AIR IN THE VALLEY THAN OVER THE PLAIN. A VALLEY MAY HAVE ONLY FROM ONE-HALF TO THREE-FOURTHS THE VOLUME OF AIR AS THE SAME AREA OVER THE PLAIN. SECOND, THE SLOPE WIND CIRCULATION IS AN EFFICIENT MECHANISM FOR DISTRIBUTING THE HEAT IN THE VALLEY. THIRD,	VU-GRAPH #9

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TIME	LESSON OUTLINE	AIDS & CUES
	THE AIR IN THE VALLEY IS SOMEWHAT PROTECTED FROM THE GRADIENT WIND ABOVE BY THE RIDGES SURROUNDING THE VALLEY.	
	AT NIGHT THE COOLING INFLUENCE OF THE COLD SLOPES OF THE VALLEY COOLS THE VALLEY AIR MORE THAN THE AIR AT THE SAME LEVEL OVER THE PLAIN IS COOLED. AGAIN THE LARGER SURFACE IN THE VALLEY OPERATES ON A SMALLER VOLUME OF AIR, AND THE EFFICIENT SLOPE CIRCULATION CONTINUES TO BRING NEW AIR IN CONTACT WITH THE COLD SLOPES. AS A RESULT OF THE TEMPERATURE DIFFERENCE THE PRESSURE AT THE FLOOR OF THE VALLEY BECOMES GREATER THAN THAT AT THE SAME ELEVATION OVER THE PLAIN. THIS LOCAL PRESSURE GRADIENT FORCES THE AIR TO FLOW TOWARD THE PLAIN AS A DOWN-VALLEY WIND. AT AN ELEVATION APPROXIMATELY THE SAME AS THE RIDGE HEIGHT THE PRESSURES ARE THE SAME OVER THE VALLEY AND OVER THE PLAIN. ABOVE THIS HEIGHT THERE IS A RETURN FLOW OF AIR FROM OVER THE PLAIN TO OVER THE VALLEY.	VU-GRAPH #10

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TIME	LESSON OUTLINE	AIDS & CUES
	TO UNDERSTAND THE MECHANICS OF THE SLOPE AND VALLEY WINDS IT IS NECESSARY TO EXAMINE THEM IN MORE DETAIL AND SEE HOW THEY CHANGE FROM DAY TO NIGHT. DURING THE FORENOON STRONG UP-SLOPE WINDS DEVELOP AS THE AIR NEXT TO THE SLOPES BECOMES WARMER THAN THAT AT THE SAME ELEVATION OVER THE VALLEY FLOOR. THE AIR IS BEING HEATED ALONG THE SLOPES BY CONTACT WITH THE SLOPES AND IN THE MIDDLE OF THE VALLEY BY COMPRESSION WHERE IT IS DESCENDING. THIS IS A MECHANISM BY WHICH THE WHOLE MASS OF AIR IN THE VALLEY IS WARMED. AT THIS TIME OF THE DAY THE VALLEY AIR TEMPERATURES ARE ABOUT THE SAME AS THOSE OVER THE PLAIN. IT IS THE TRANSITION PERIOD BETWEEN THE UP-VALLEY WIND AND THE DOWN-VALLEY WIND.	
	AROUND NOON AND EARLY AFTERNOON THE SLOPE CIRCULATION BEGINS TO DIMINISH BUT THE UP-VALLEY WIND IS FULLY DEVELOPED AND AT ITS MAXIMUM. THE VALLEY AIR IS NOW WARMER THAN THAT OVER THE PLAIN.	VU-GRAPH #11

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TIME	LESSON OUTLINE	AIDS & CUES
	BY LATE AFTERNOON THE SLOPES ARE BEGINNING TO COOL AND THE SLOPE WINDS HAVE CEASED. THE VALLEY AIR IS STILL WARMER THAN THAT OVER THE PLAIN SO THE UP-VALLEY WIND CONTINUES.	
	AS THE SLOPES CONTINUE TO COOL, DOWN-SLOPE WINDS BEGIN 1/4 TO 3/4 HOUR AFTER SUNSET. THE UP-VALLEY WIND DIMINISHES DURING THE EARLY EVENING SINCE THE VALLEY AIR BY THEN IS ONLY SLIGHTLY WARMER THAN THAT OVER THE PLAIN.	
	BY EARLY NIGHT THE DOWN-SLOPE WINDS ARE WELL DEVELOPED. AIR ALONG THE SLOPES IS BEING COOLED BY CONTACT WITH THE COOL SLOPES, AND IN THE MIDDLE OF THE VALLEY WHERE AIR IS ASCENDING IT IS BEING COOLED BY EXPANSION (ADIABATIC COOLING). THIS IS THE MECHANISM BY WHICH THE WHOLE MASS OF AIR IN THE VALLEY BECOMES COOLED. EARLY NIGHT IS THE TRANSITION PERIOD BETWEEN UP-VALLEY WINDS AND DOWNVALLEY WINDS. THE VALLEY AIR TEMPERATURES ARE ABOUT THE SAME AS THOSE OVER THE PLAIN.	VU-GRAPH #12
	THE DOWN-SLOPE WINDS CONTINUE DURING THE MIDDLE OF THE NIGHT. THE DOWN-VALLEY WIND IS FULLY	

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TIME	LESSON OUTLINE	AIDS & CUES
	DEVELOPED, HOWEVER, SINCE THE VALLEY AIR IS MUCH COLDER THAN THAT OVER THE PLAIN.	
	DURING LATE NIGHT AND EARLY MORNING THE DOWN-VALLEY WIND CONTINUES AND FILLS THE VALLEY. THE VALLEY AIR IS STILL COLDER THAN THAT OVER THE PLAIN. THE DOWN-SLOPE WINDS HAVE CEASED.	
	AS SOON AS THE SUN RISES IT BEGINS TO HEAT THE SLOPES. BY 1/4 TO 3/4 HOUR AFTER SUNRISE THE UP-SLOPE WINDS BEGIN. THE DOWN-VALLEY WIND STILL CONTINUES BUT IS DIMINISHING, SINCE THE VALLEY AIR IS ONLY SLIGHTLY WARMER THAN THAT OVER THE PLAIN.	
1340	DURING THE DOWN-VALLEY WIND PERIOD THE VERTICAL DISTRIBUTION OF WIND SPEED SHOWS A MAXIMUM JUST ABOVE THE VALLEY FLOOR. THIS IS THE SLOPE WIND ALONG THE VALLEY FLOOR. ABOVE THAT THE TRUE DOWN-VALLEY WIND MAXIMUM APPEARS. THE GRADIENT WIND IS EVIDENT ABOVE THE RIDGE HEIGHT. DURING THE UP-VALLEY WIND THERE IS NO NOTICEABLE UP-SLOPE WIND ALONG THE VALLEY FLOOR PROBABLY BECAUSE OF INSTABILITY AND MIXING WITH THE UP-VALLEY WIND.	

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TIME	LESSON OUTLINE	AIDS & CUES
	WIND SPEEDS MAY BE 10-15 MILES PER HOUR. THE MINIMUM WIND SPEED OCCURS NEAR THE RIDGE HEIGHT AND ABOVE THAT GRADIENT WIND IS AGAIN EVIDENT. THE UP-SLOPE WINDS CAUSE SLOPE FIRES TO RUN FASTER TOWARD THE TOP OF A RIDGE AND BURN IN A NARROWER FRONT ON UNIFORM SLOPES. UP-VALLEY WINDS TEND TO BE MORE GUSTY AND TURBULENT THAN DOWNVALLEY. DURING THE DAYTIME THE AIR IS BEING HEATED AND TENDS TOWARD INSTABILITY. CONSIDERABLE TURBULENCE MAY BE NOTED NEAR RIDGE TOPS WHERE AIR CURRENTS FROM DIFFERENT DIRECTIONS MEET. DOWN-VALLEY WINDS HAVE LAMINAR FLOW BECAUSE THE AIR AT NIGHT BECOMES STABLE.	
	THE DEPTH OF THE VALLEY WIND IS DETERMINED PRINCIPALLY BY THE HEIGHT OF THE RIDGES ON THE SIDES OF THE VALLEY AND BY THE EFFECT OF THE GRADIENT WIND. IN GENERAL, THE DEPTH OF THE UP-VALLEY WIND WILL BE ABOUT THE SAME AS THE AVERAGE RIDGE HEIGHT, AND THE DEPTH OF THE DOWN-VALLEY WIND IS SOMEWHAT LESS. THE INFLUENCE OF THE GRADIENT WIND WILL BE DISCUSSED IN MORE DETAIL LATER. HERE IT IS SUFFICIENT TO POINT OUT THAT	VU-GRAPH #2

TIME	LESSON OUTLINE	AIDS & CUES

WHEN A GRADIENT BLOWS ALONG THE AXIS OF A VALLEY AND IN THE SAME DIRECTION OF THE UP-VALLEY WIND, THE EFFECTS OF THE UP-VALLEY WIND ARE EVIDENT WELL ABOVE THE RIDGES. WHEN THE GRADIENT WIND BLOWS IN THE OPPOSITE DIRECTION, THE EFFECT IS TO REDUCE THE DEPTH OF THE UP-VALLEY WIND. GRADIENT WINDS HAVE LITTLE EFFECT ON THE DEPTH OF THE DOWN-VALLEY WIND BECAUSE THE INVERSION THAT IS PRODUCED EFFECTIVELY SHIELDS THE AIR IN THE CANYON.

THE TRANSITION PERIOD FROM DOWN-VALLEY TO UP-VALLEY WIND IS RATHER SHORT, USUALLY LESS THAN AN HOUR. A FAIRLY DEEP LAYER OF AIR BEGINS TO MOVE UP-VALLEY AND WITHIN A SHORT TIME BUILDS UP TO ITS MAXIMUM VERTICAL EXTENT. THE TRANS-SITION FROM UP-VALLEY TO DOWN VALLEY WIND TAKES PLACE MORE SLOWLY. THE SLOPE WIND ALONG THE VALLEY FLOOR BEGINS AS A LAMINAR FLOW THAT DEEP-ENS DURING THE NIGHT AND BECOMES INTEGRATED WITH THE TRUE DOWN-VALLEY WIND.

THE TIME THAT THE VALLEY WIND REVERSAL TAKES PLACE IS DEPENDENT UPON THE SIZE OF THE VALLEY.

TIME	LESSON OUTLINE	AIDS & CUES
	A SMALL VALLEY CONTAINS A SMALLER VOLUME OF AIR AND IS THEREFORE MORE SENSITIVE TOTTHE FORCES ACTING ON IT. THE SMALLER THE VALLEY THE SOONER AFTER SUNRISE AND SUNSET THE WIND REVERSAL TAKES PLACE.	
	THE SHAPE OF THE VALLEY IS ONE OF THE FACTORS THAT AFFECTS VALLEY WINDS. VALLEYS MAY BE DIVIDED INTO TWO TYPES, THE U-SHAPED VALLEY AND THE V-SHAPED VALLEY. THE U-SHAPED VALLEY IS OLD GEOLOGICALLY. THE VALLEY FLOOR IS BROAD AND THE SLOPES ALONG ITS MAJOR AXIS IS SMALL. THE VALLEY IS LARGE AND ITS SIDES SLOPE GENTLY. IT IS IN THE U-SHAPED VALLEY THAT THE VALLEY WINDS REACH THEIR GREATEST DEVELOPMENT.	VU-GRAPH #13
	THE V-SHAPED VALLEY IS SMALLER AND YOUNGER THAN THE U-SHAPED VALLEY. THE VALLEY FLOOR IS NARROW AND STEEP, AND THE SIDES RISE ABRUPTLY FROM THE VALLEY FLOOR. THE WIND BEHAVIOR IN A V-SHAPED VALLEY IS ERRATIC BECAUSE OF ITS ROUGHNESS AND BECAUSE THE PRESSURE GRADIENT BETWEEN THE VALLEY AND THE PLAIN IS SMALL. EDDIES BECOME QUITE IMPORTANT.	VU-GRAPH #14

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TIME	LESSON OUTLINE	AIDS & CUES
	THE GRADIENT WIND HAS ITS MAXIMUM EFFECT ON SLOPE WINDS IN THE DAYTIME AND WHEN IT IS STRONG AND BLOWING PARALLEL TO THE VALLEY.	
	THE THERMAL STRUCTURE OF SLOPE WINDS DETERMINES THEIR FLOW CHARACTERISTICS. UP-SLOPE WINDS, BEING PRODUCED BY THE HEATING OF THE SLOPES, TEND TO BE TURBULENT BECAUSE THE THERMAL STRUCTURE OF THE AIR TENDS TOWARD INSTABILITY. AT NIGHT A SHALLOW INVERSION FORMS NEXT TO THE SLOPE.	VU-GRAPH #15
	DOWN-SLOPE WINDS IN THIS STABLE AIR ARE CHARACTERIZED BY LAMINAR FLOW. BECAUSE OF THE SHALLOWNESS OF THE LAYER, HEAT FROM FIRES MAY BE CONFINED TO THE GROUND AND DRIVEN INTO THE FUELS AHEAD. RAPID SPREAD RESULTS. AIR FLOWING DOWNSLOPE MAY ALSO BE DAMMED UP TEMPORARILY BY OBSTRUCTIONS AND SUDDENLY RELEASED CAUSING A GUSTY CONDITION. DOWN-SLOPE AIR TENDS TO CHANNEL, FOLLOWING THE TOPOGRAPHY.	
	FROM THE PREVIOUS DISCUSSION OF SLOPE AND VALLEY WINDS IT IS EVIDENT TO AN OBSERVER ON THE SLOPE OF A VALLEY THAT THE WIND DIRECTION ROTATES AS THE DAY PROGRESSES.	VU-GRAPH #16

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TIME	LESSON OUTLINE	AIDS & CUES
	SINCE SLOPE WINDS ARE SENSITIVE TO LOCAL HEATING AND COOLING WILL ALSO AFFECT THE SLOPE WINDS. EXPOSURE IS THE PRIMARY FACTOR AFFECTING UP-SLOPE WINDS. SINCE SOUTH AND WEST ASPECTS RECEIVE MORE HEAT FROM THE SUN THEY ALSO HAVE THE STRONGEST WINDS. SOUTHWEST EXPOSURES AND CANYONS DRAINING FROM THE NORTHEAST TO THE SOUTHWEST USUALLY HAVE THE STRONGEST, MOST TURBULENT UP-SLOPE AND UP CANYON DIURNAL WINDS.	
1345	c) <u>FIRE WHIRLWINDS</u>	
	THE HEAT GENERATED BY FIRES CAN PRODUCE EXTREME INSTABILITY IN THE LOWER AIR AND BE THE CAUSE OF VIOLENT FIRE WHIRLWINDS.	
	FIRE WHIRLWINDS OCCUR MOST FREQUENTLY WHERE HEAVY CONCENTRATIONS OF FUELS ARE BURNING AND A LARGE AMOUNT OF HEAT IS BEING PRODUCED IN A SMALL AREA. THEY TEND TO FAVOR THE LEE SIDE OF RIDGES, NEAR RIDGETOPS, AND BENCHES ON THE UPPER THIRD OF SLOPES.	VU-GRAPH #16A

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TIME	LESSON OUTLINE	AIDS & CUES
	D). THUNDERSTORM WINDS	
	WINDS FROM MATURE THUNDERHEADS ALWAYS BLOW AWAY FROM THE STORM. THEREFORE, THE SAFEST AREA IS BETWEEN THE FIRE AND THE THUNDERSTORM. THESE CONVECTION COLUMNS WILL HAVE A SHORT LIVED, BUT VIOLENT EFFECT ON FIRES, WITH WINDS AS HIGH AS 20 - 30 M.P.H. IMMATURE THUNDERSTORMS ALSO HAVE THE EFFECT OF INCREASING UPSLOPE WINDS BECAUSE OF THE UPDRAFT INTO THEM.	
1350	3. MECHANICAL EFFECTS OF TOPOGRAPHY.	
	(A) EDDIES. AS AIR FLOWS OVER ROUGH TOPOGRAPHY EDDIES ARE CREATED JUST AS THEY ARE IN FLOW OF WATER IN A STREAM. THE NUMBER AND INTENSITY OF THE EDDIES INCREASES WITH THE ROUGHNESS OF THE TOPOGRAPHY AND WITH THE SPEED OF THE WIND FLOW.	
	IF THE MOUNTAINS OR RIDGES ARE STEEP, ON THE LEE SIDES, ROLL EDDIES FORM AS WIND BLOWS OVER THEM. WHEN WINDS ARE MODERATE THE ROLL EDDY TENDS TO REMAIN JUST OVER THE RIDGE OF THE LEE SIDE. WHEN WINDS ARE STROND, HOWEVER, THE AIR FLOWSIS BROKEN UP INTO MANY EDDIES MAKING THE LEE SIDE VERY	VU-GRAPH #17

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TIME	LESSON OUTLINE	AIDS & CUES
	VERY TURBULENT. THESE EDDIES TUMBLE DOWN THE LEE SIDE AND ARE CARRIED ALONG WITH THE WIND. SMALL BUT INTENSE LOCAL DOWNDRAFTS CAN OCCUR WITH THE LEE EDDY.	
	IN ROLLING COUNTRY THE AIR IS MORE LIKELY TO FOLLOW THE SURFACE WITHOUT AN EDDY FORMING BEHIND THE RIDGE WHEN WINDS ARE MODERATE. NOT INFREQUENTLY, HOWEVER, THERE WILL BE EDDIES FORMING SOME DISTANCE FROM THE RIDGE. WHEN WINDS ARE STRONG THE EDDIES WILL BE MORE NUMEROUS.	VU-GRAPH #18
	B) <u>FUNNEL WINDS</u>. WIND, IN BLOWING AGAINST MOUNTAIN RANGES, WILL RESIST BEING LIFTED OVER THE MOUNTAINS AND RIDGES ESPECIALLY IF THE AIR IS STABLE. INSTEAD THE AIR WILL BE FORCED THROUGH PASSES AND SADDLES AT HIGH SPEEDS. THESE ARE KNOWN AS <u>FUNNEL WINDS</u>.	
	C) <u>CHANNEL OR GORGE WINDS</u>. VERY PRONOUNCED WIND EFFECTS WILL ALSO BE NOTED IN DEEP CANYONS OR GORGES THAT PROVIDE LOW-LEVEL PASSAGES THROUGH MOUNTAIN RANGES.	VU-GRAPH #19

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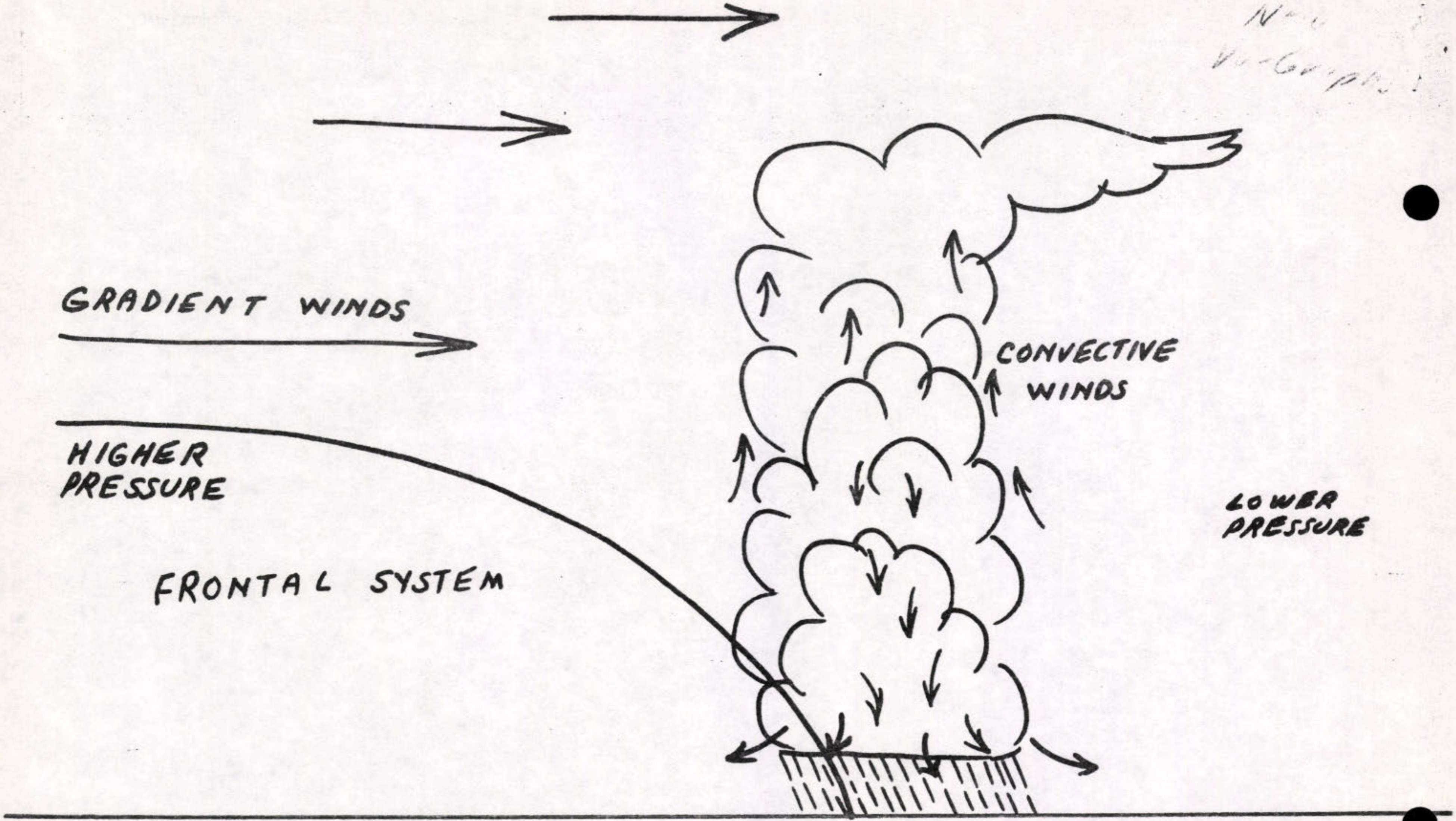
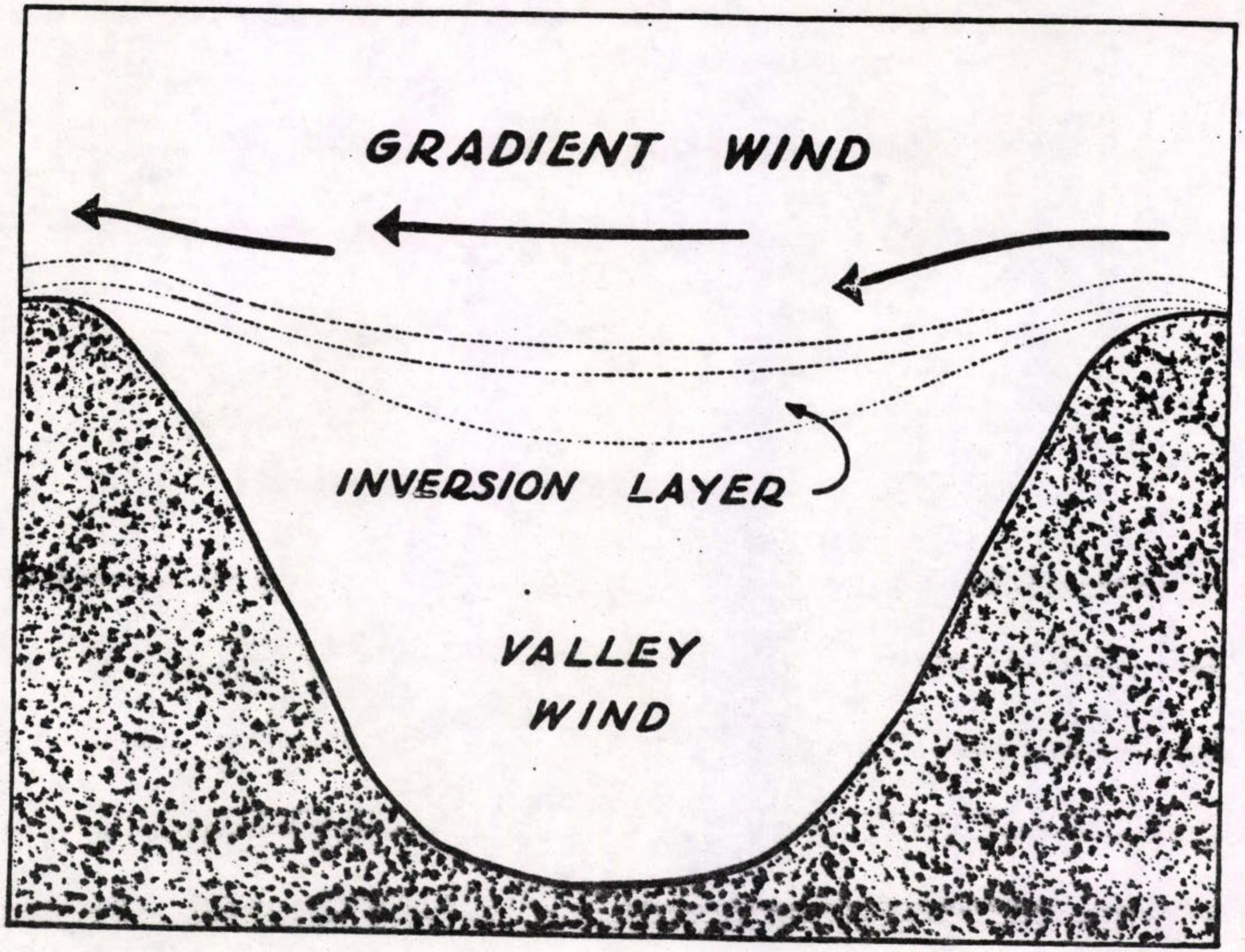
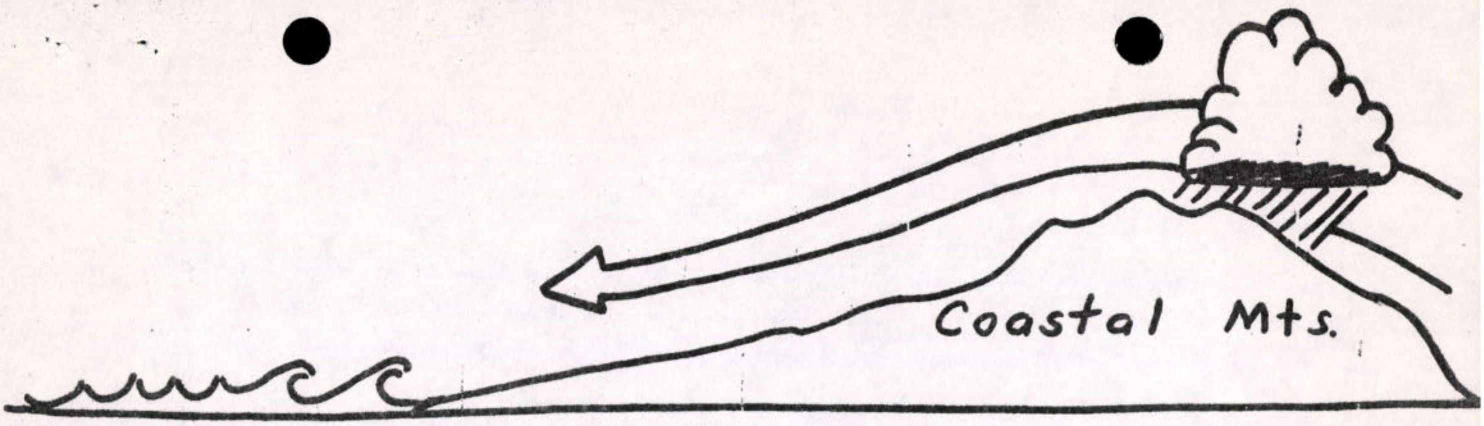
TIME	LESSON OUTLINE	AIDS & CUES
	4. INFLUENCE OF VEGETATION FOREST STAND AND OBSTRUCTIONS ON LOCAL WINDS.	
	SMALL EDDIES FORM AROUND GROUPS OF TREES, IN FOREST OPENINGS, AND AROUND OTHER OBSTRUCTIONS.	VU-GRAPHS 20 & 21
	REFERENCES FOR THIS SUBJECT ARE PAGES 86 - 126 (CHAPTERS 6 & 7) IN "FIRE WEATHER"	
1355	QUESTIONS?	

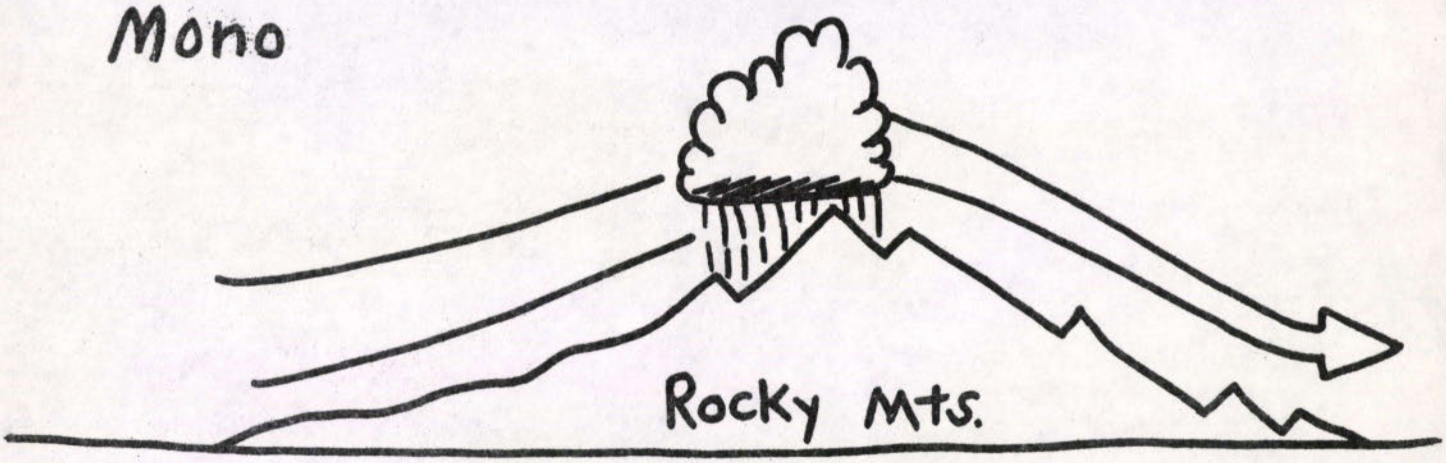

GRADIENT WINDS
CONVECTIVE WINDS
HIGHER PRESSURE
LOWER PRESSURE
FRONTAL SYSTEM


GRADIENT WIND
INVERSION LAYER
VALLEY
WIND



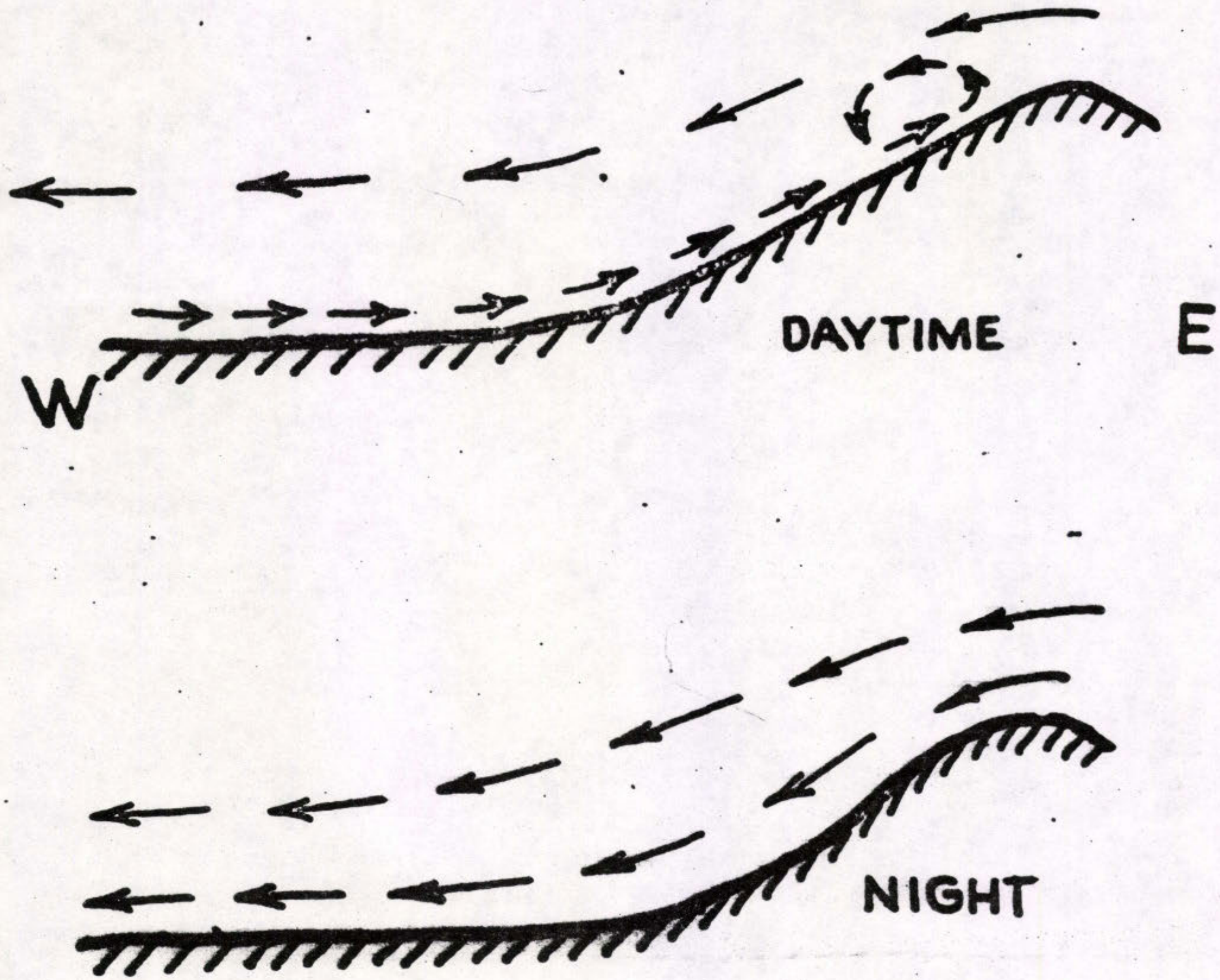
Santa Ana

Mono



Chinook

Foehn Winds


DAYTIME
E
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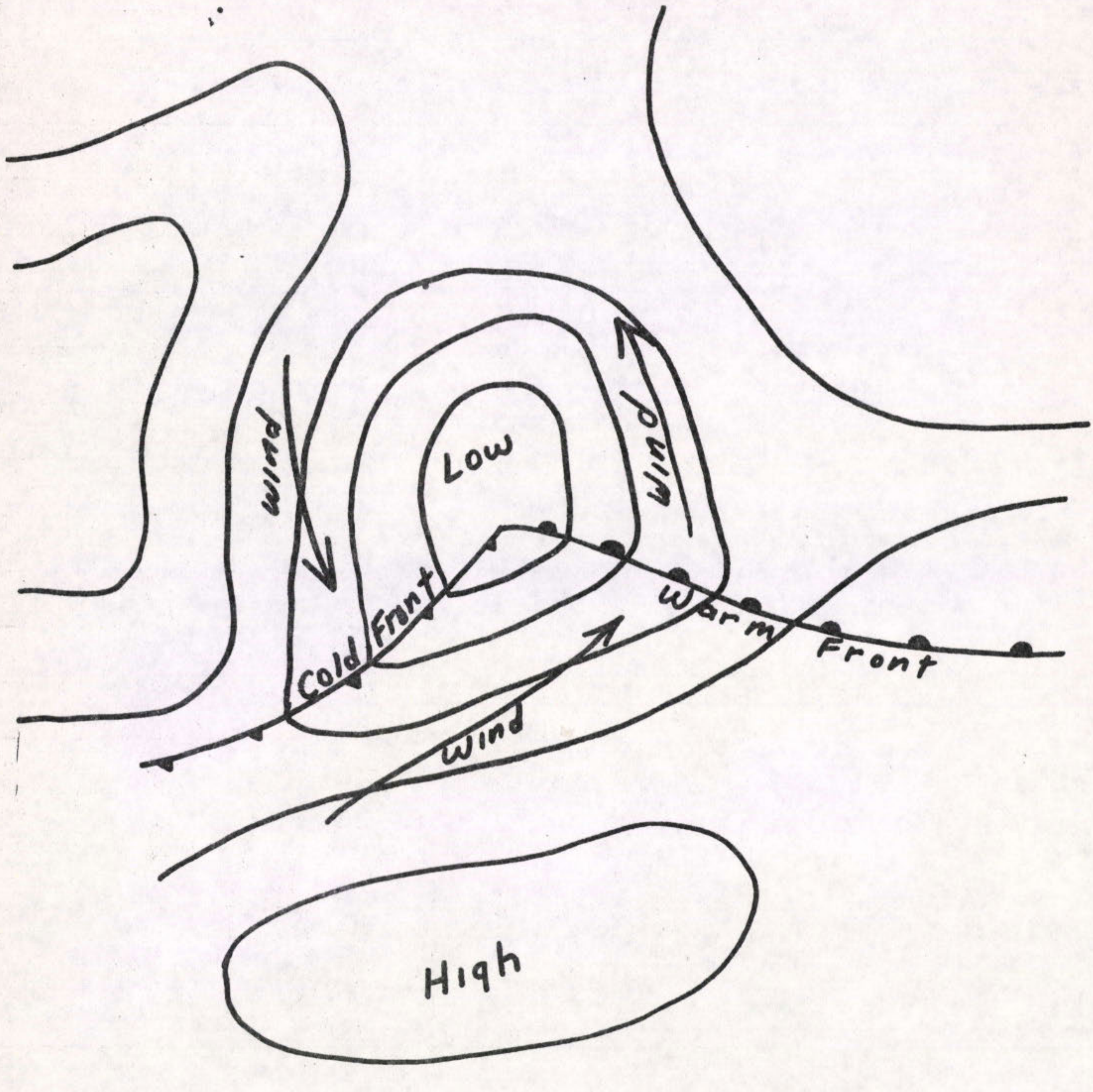
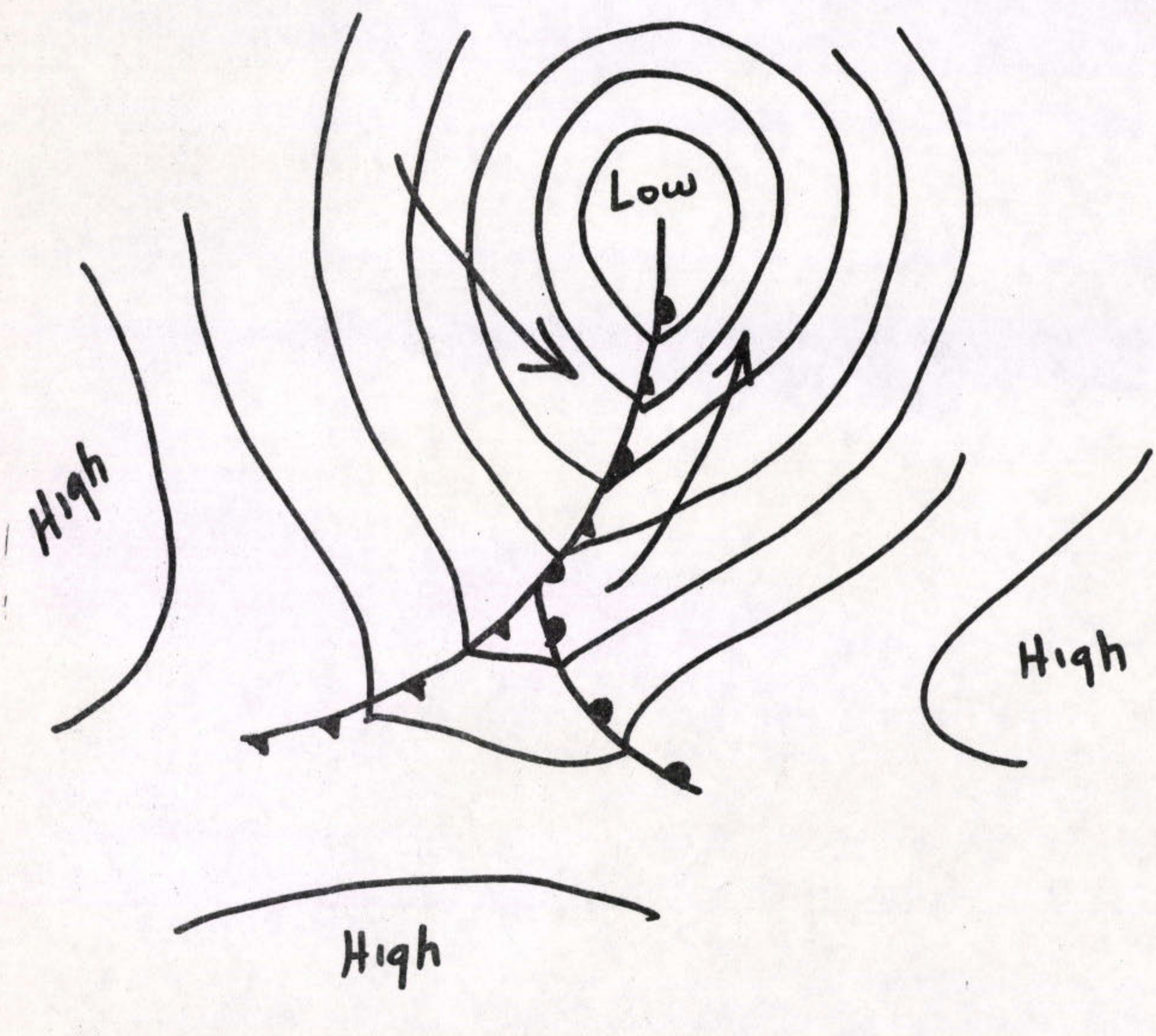
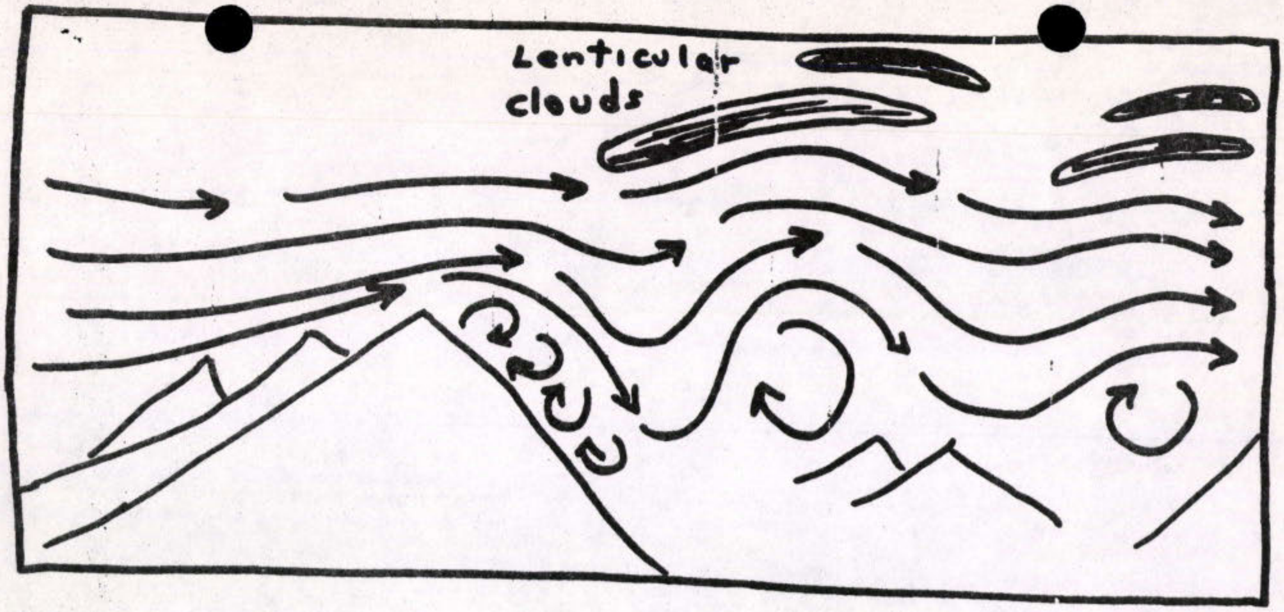
NIGHT



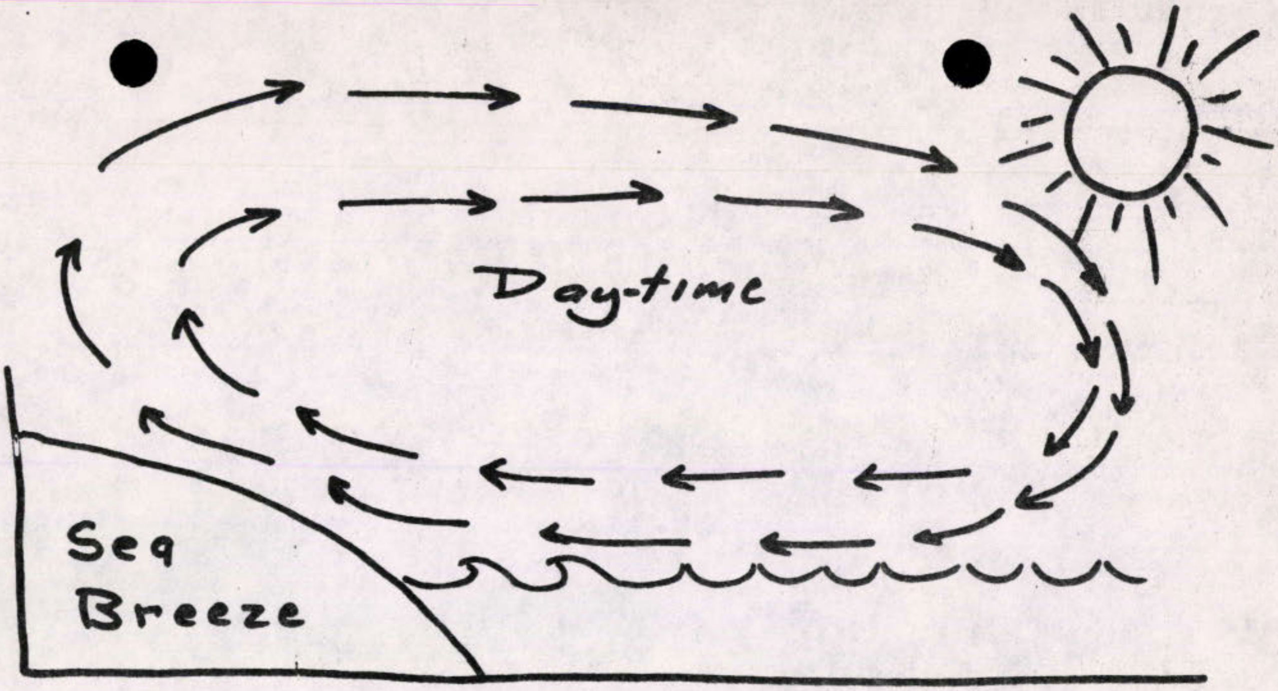
Wind Shift with Frontal Passage

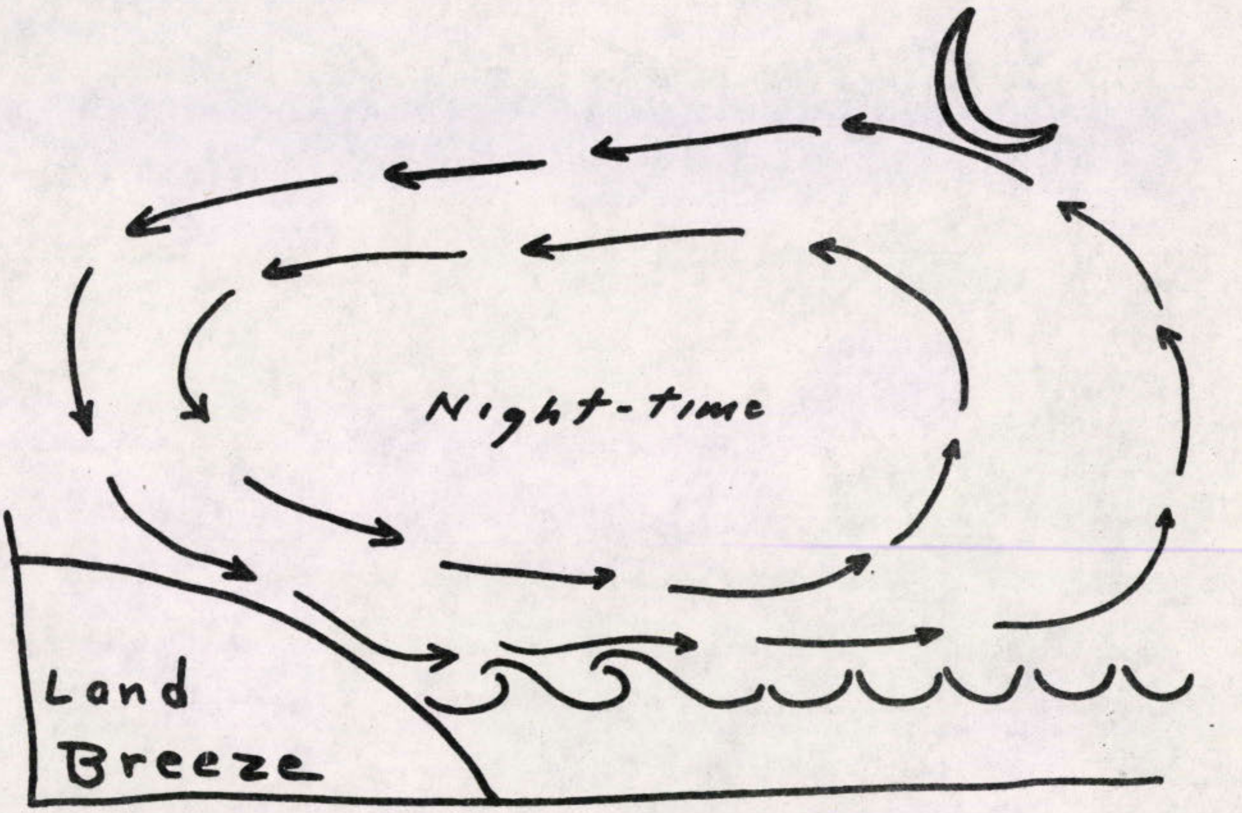
Wind Shift with Passage of an Occluded Front

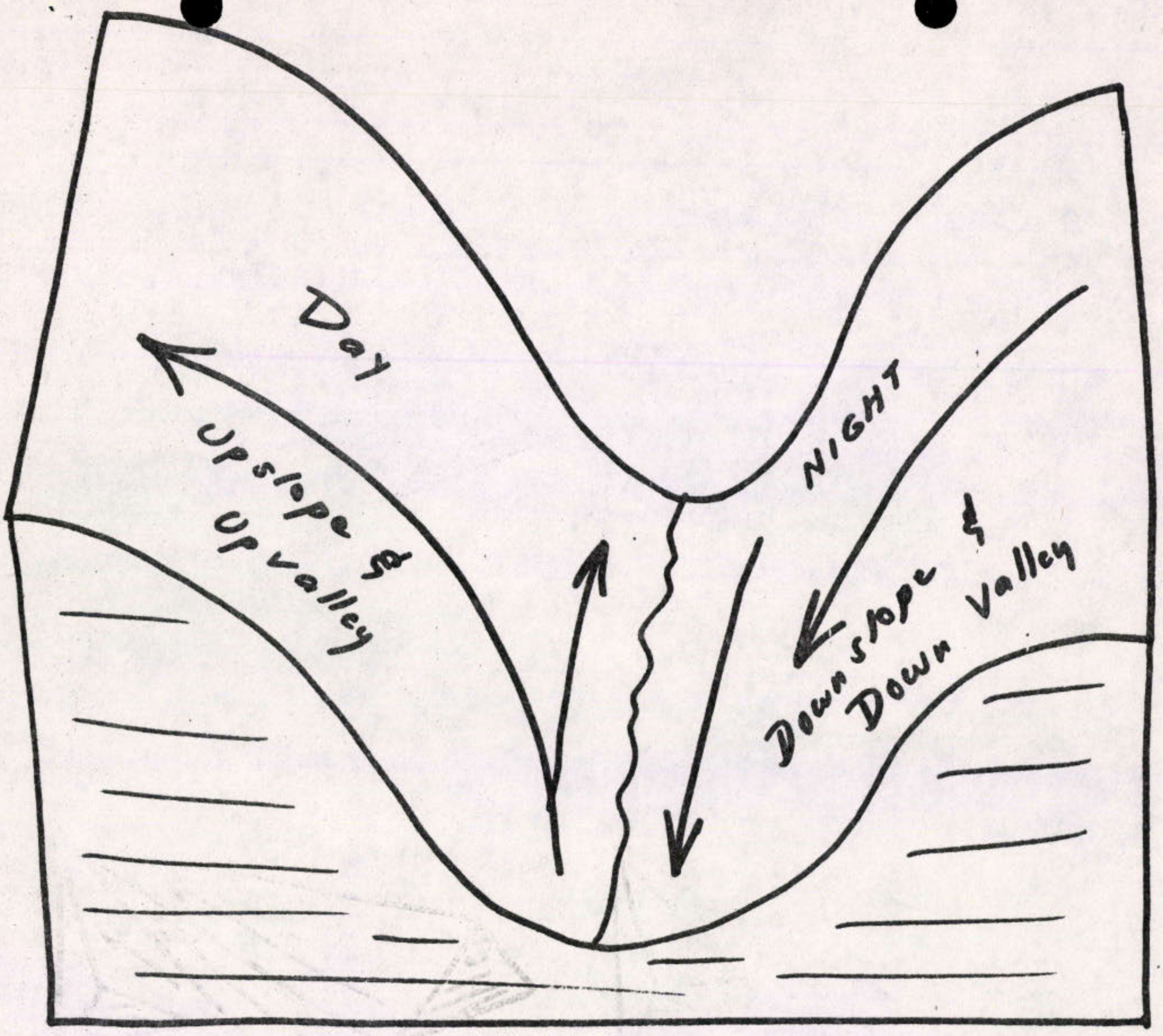


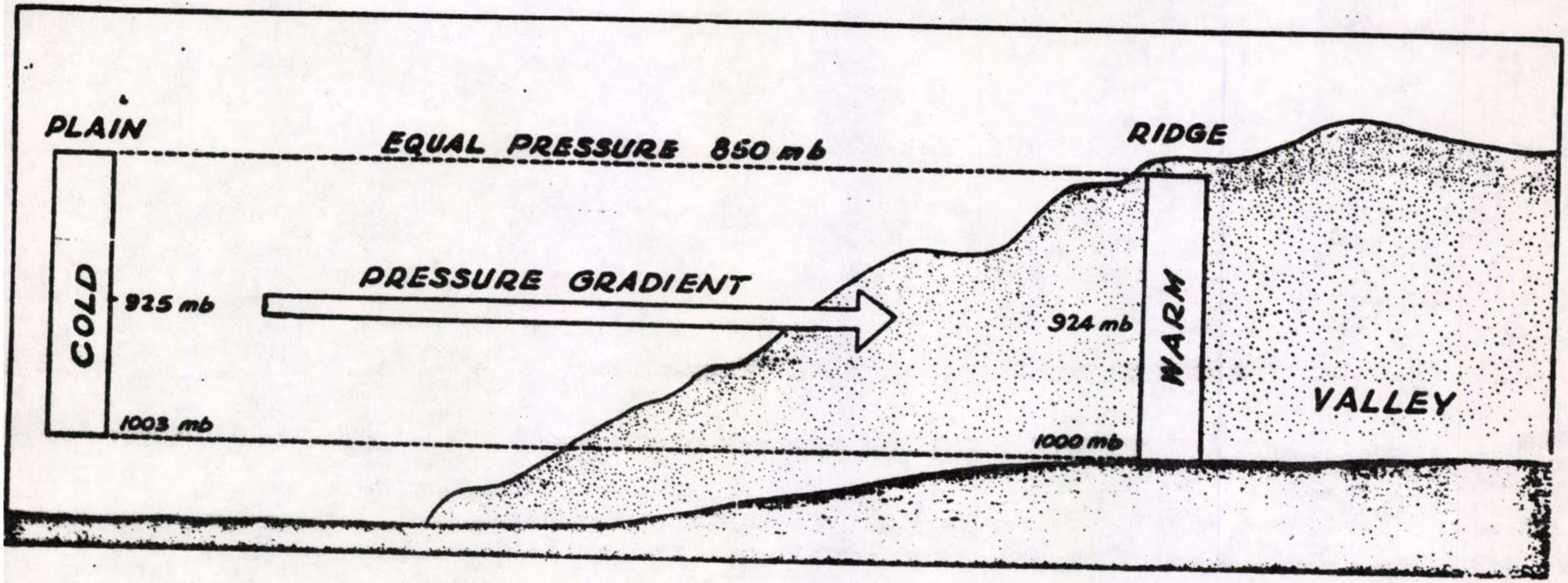


Mountain Waves

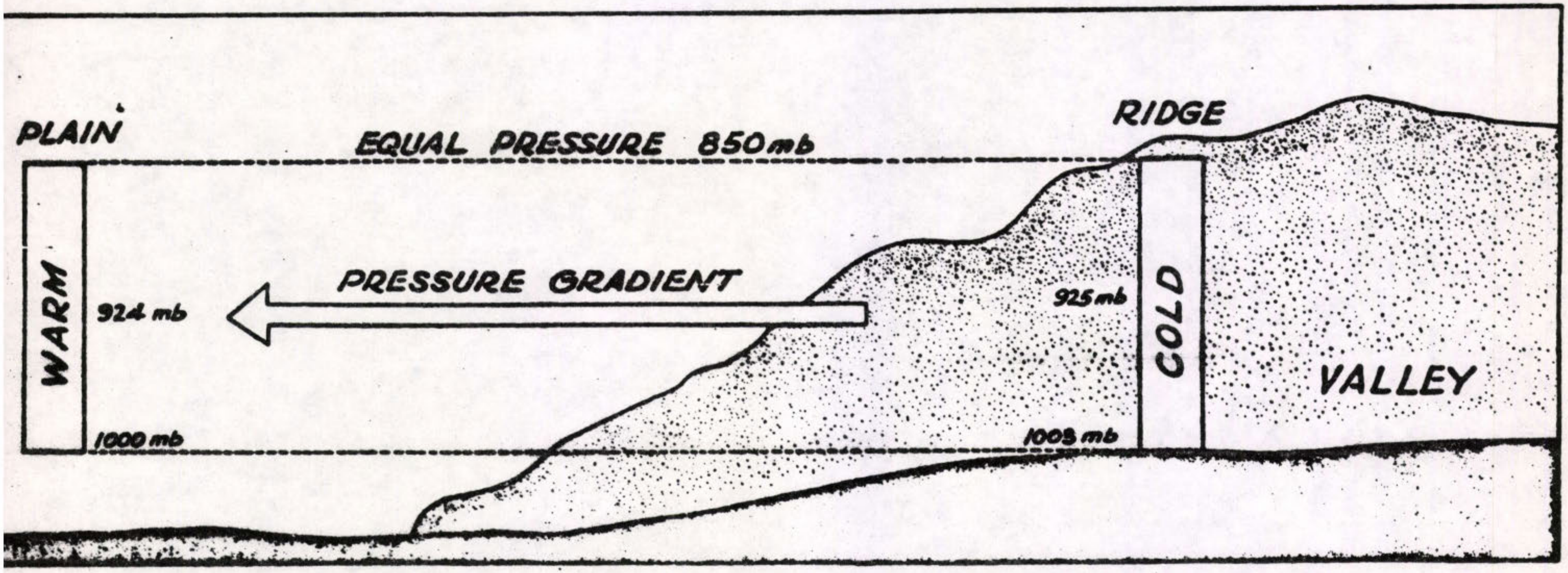

Day-time
Sea
Breeze


Night-time
Land
Breeze

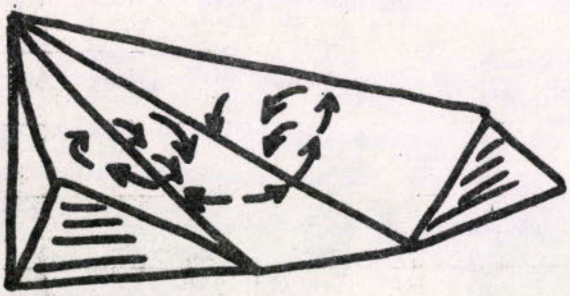

Day
Upslope &
Up valley
NIGHT
Downslope &
Down valley



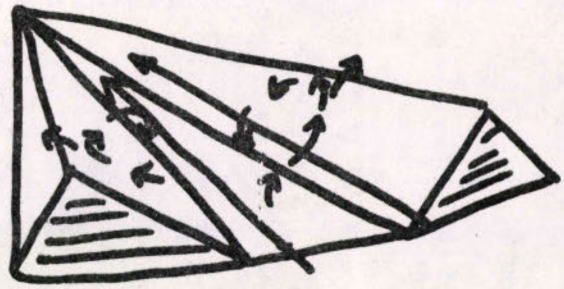
LOCAL PRESSURE GRADIENT BY DAY



LOCAL PRESSURE GRADIENT BY NIGHT

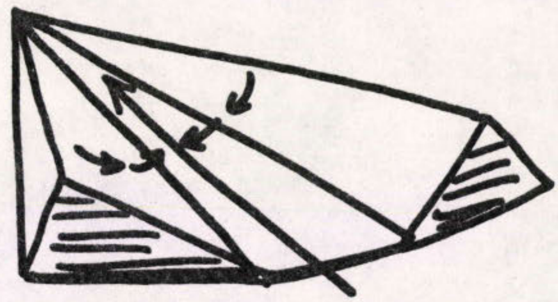


Forenoon



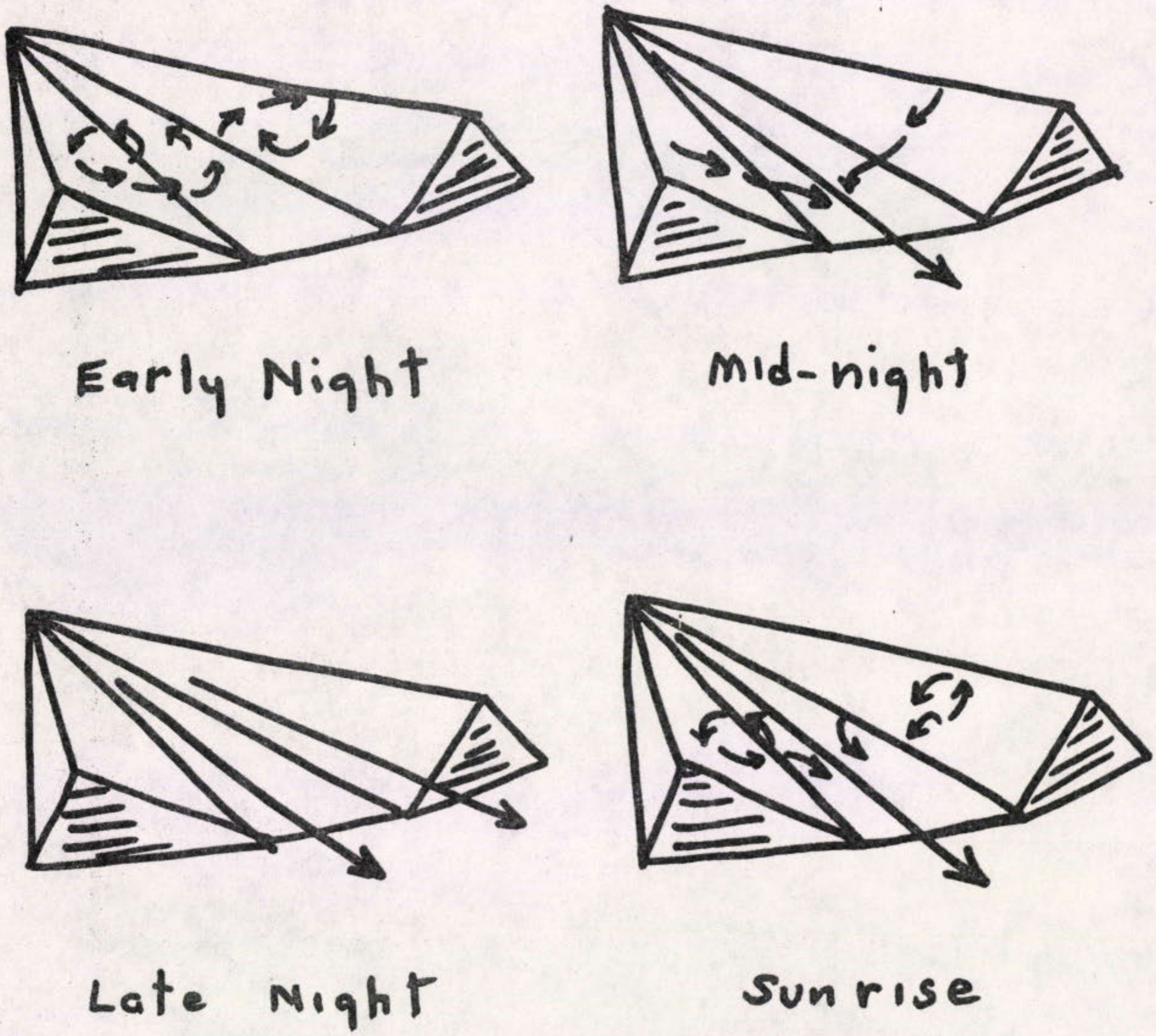
Noon

Late Afternoon

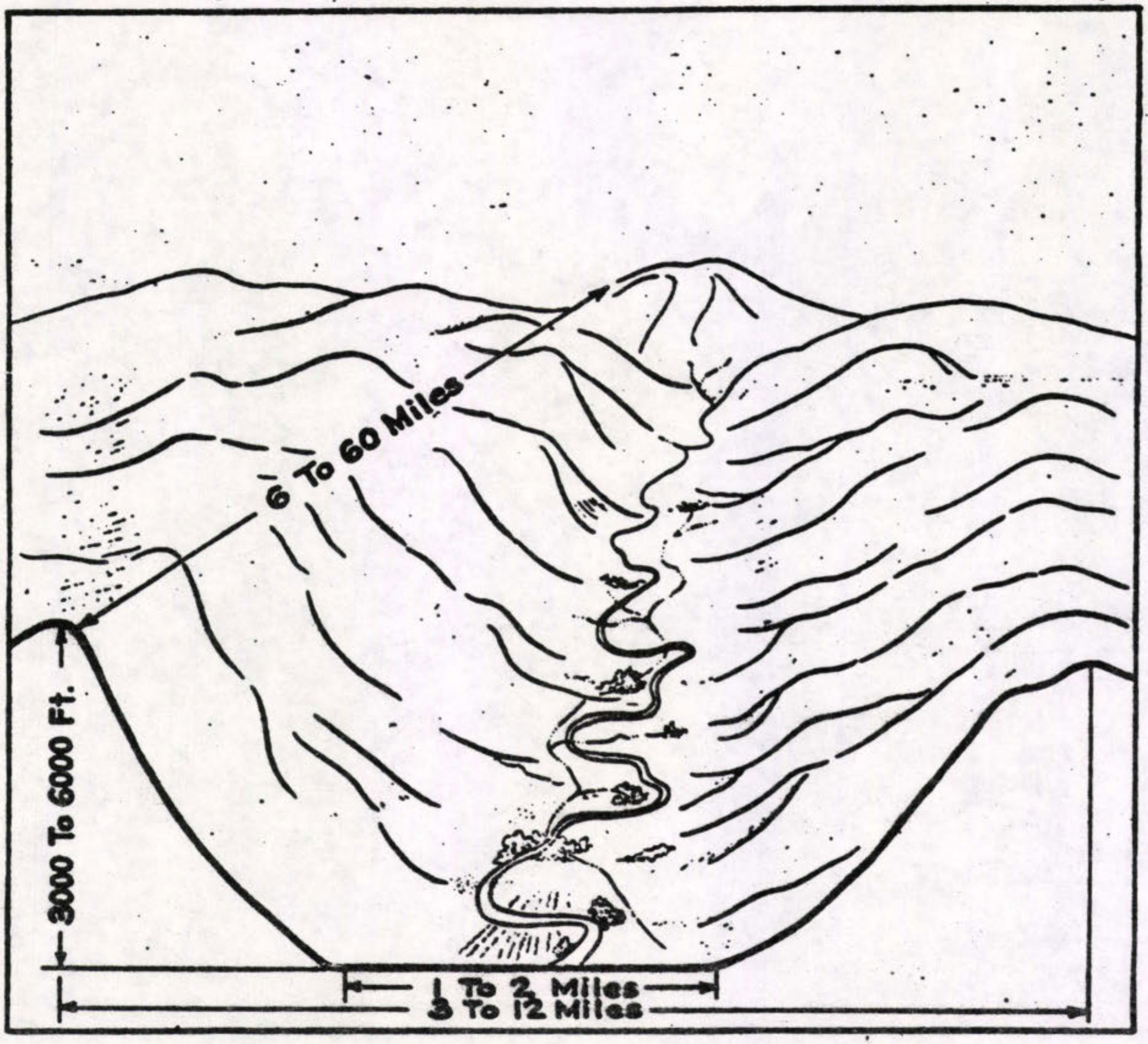


Evening

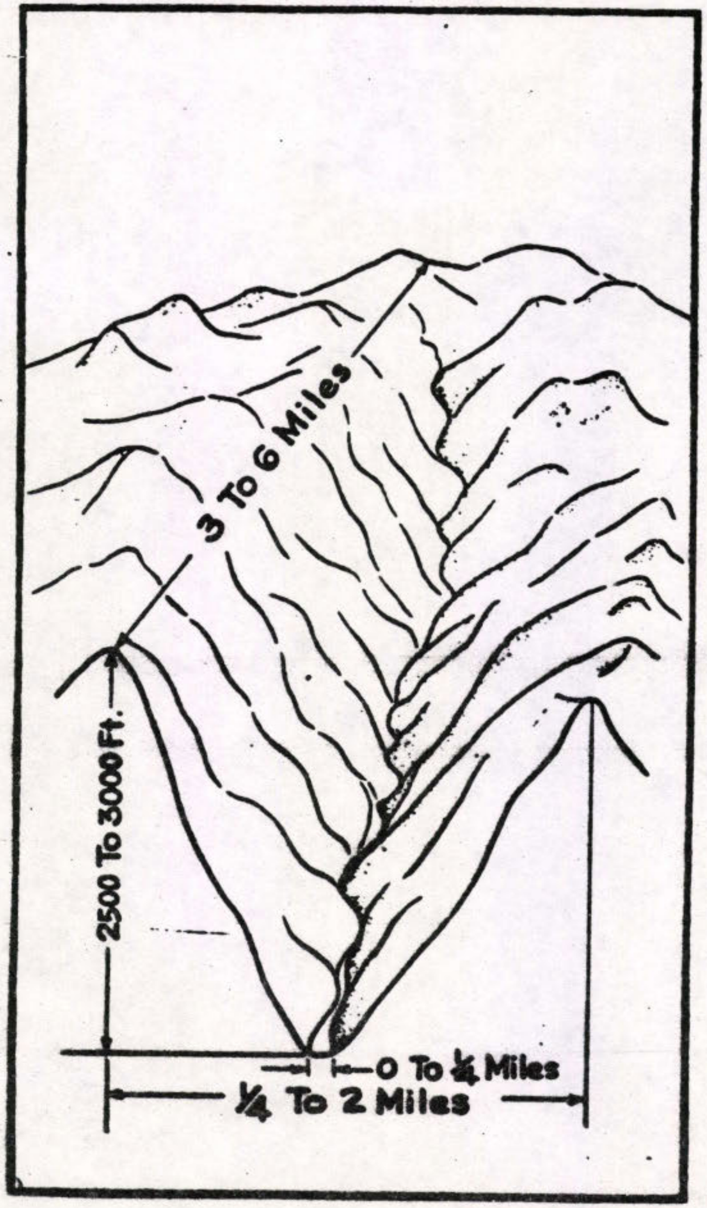
Day Slope & Valley Winds



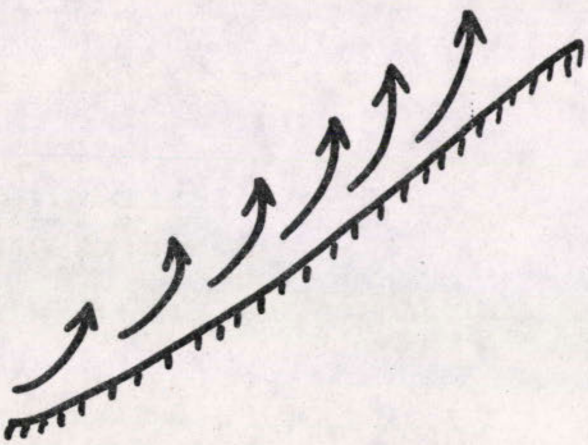
Night Slope & Valley Winds



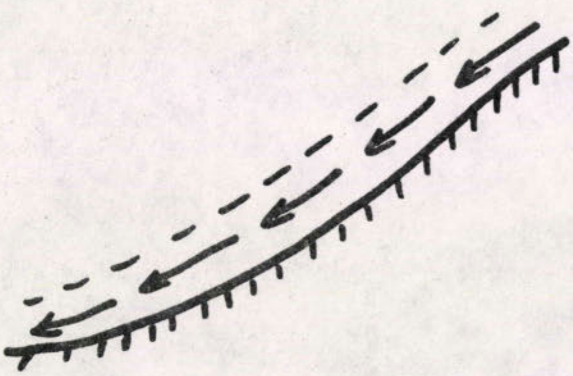
U SHAPED VALLEY



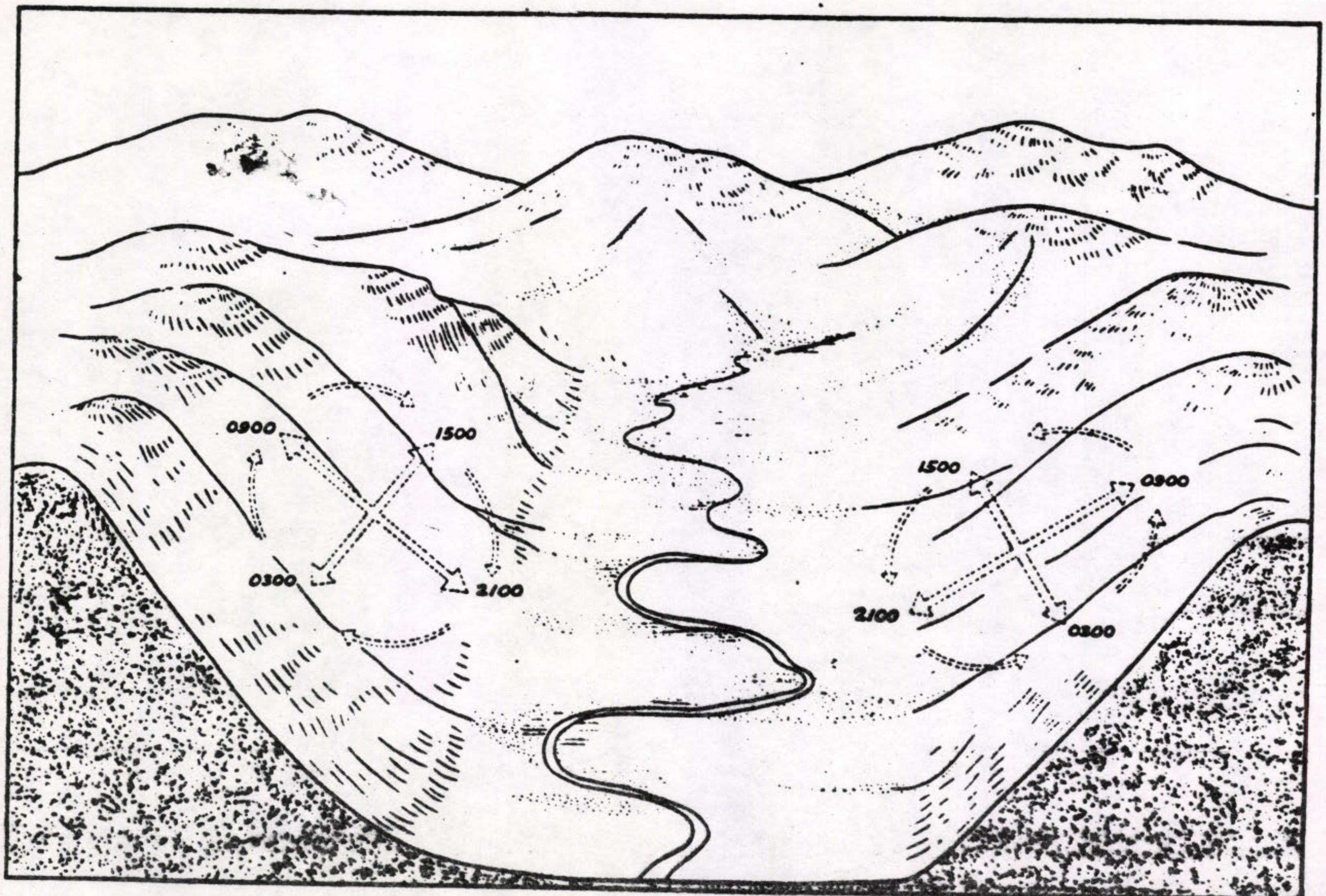
V-SHAPED VALLEY



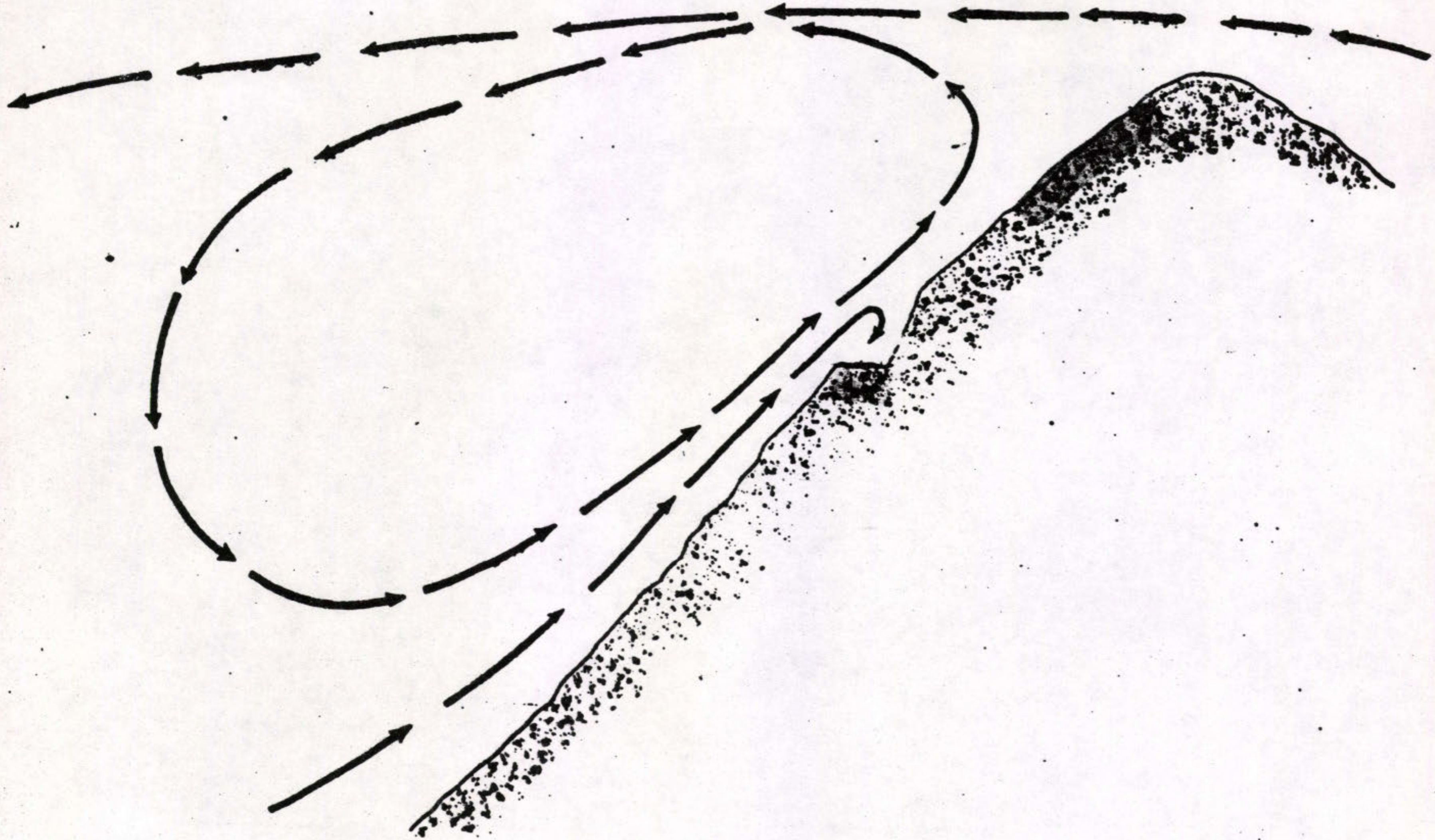
Turbulent Flow by Day



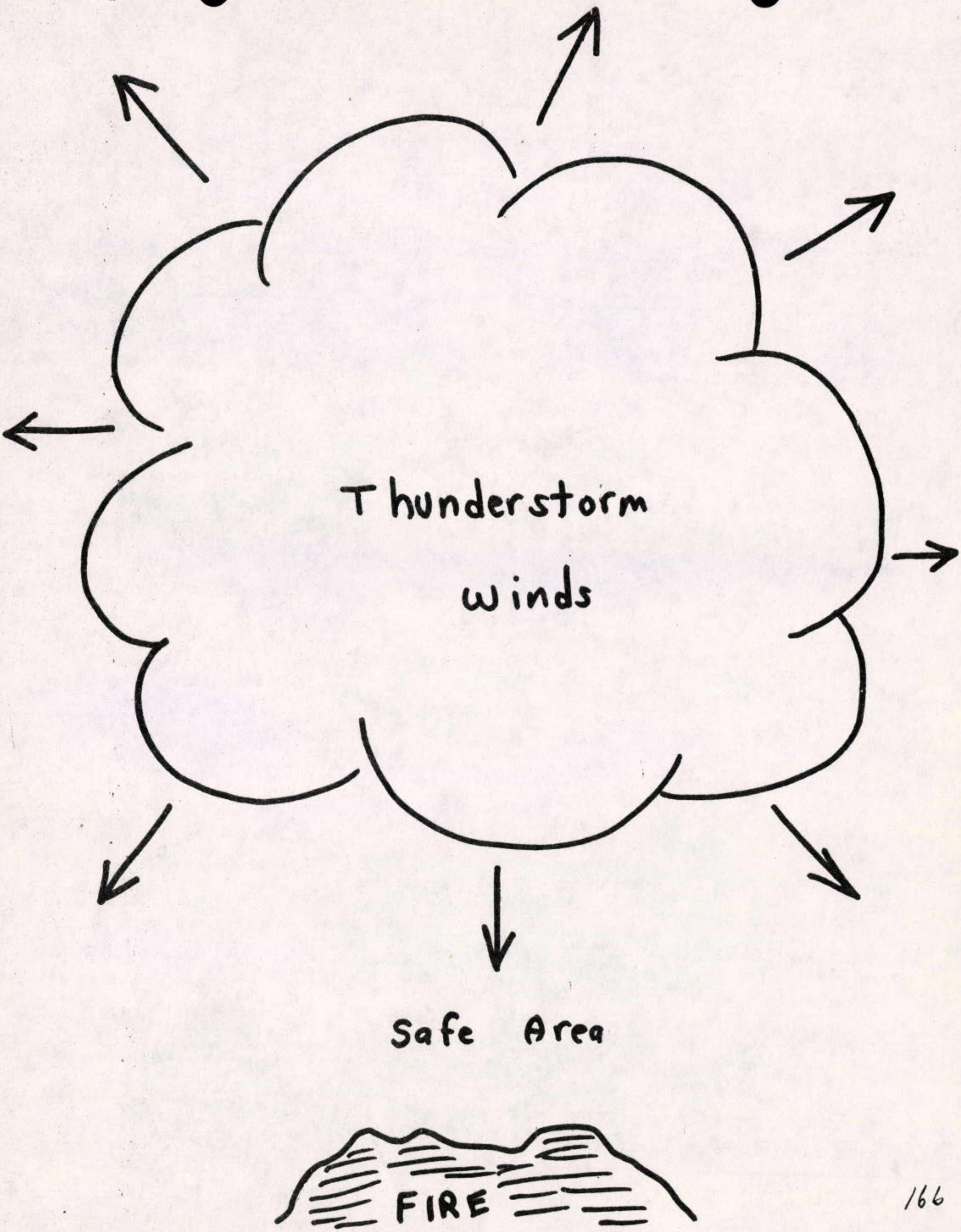
Laminar Flow by Night



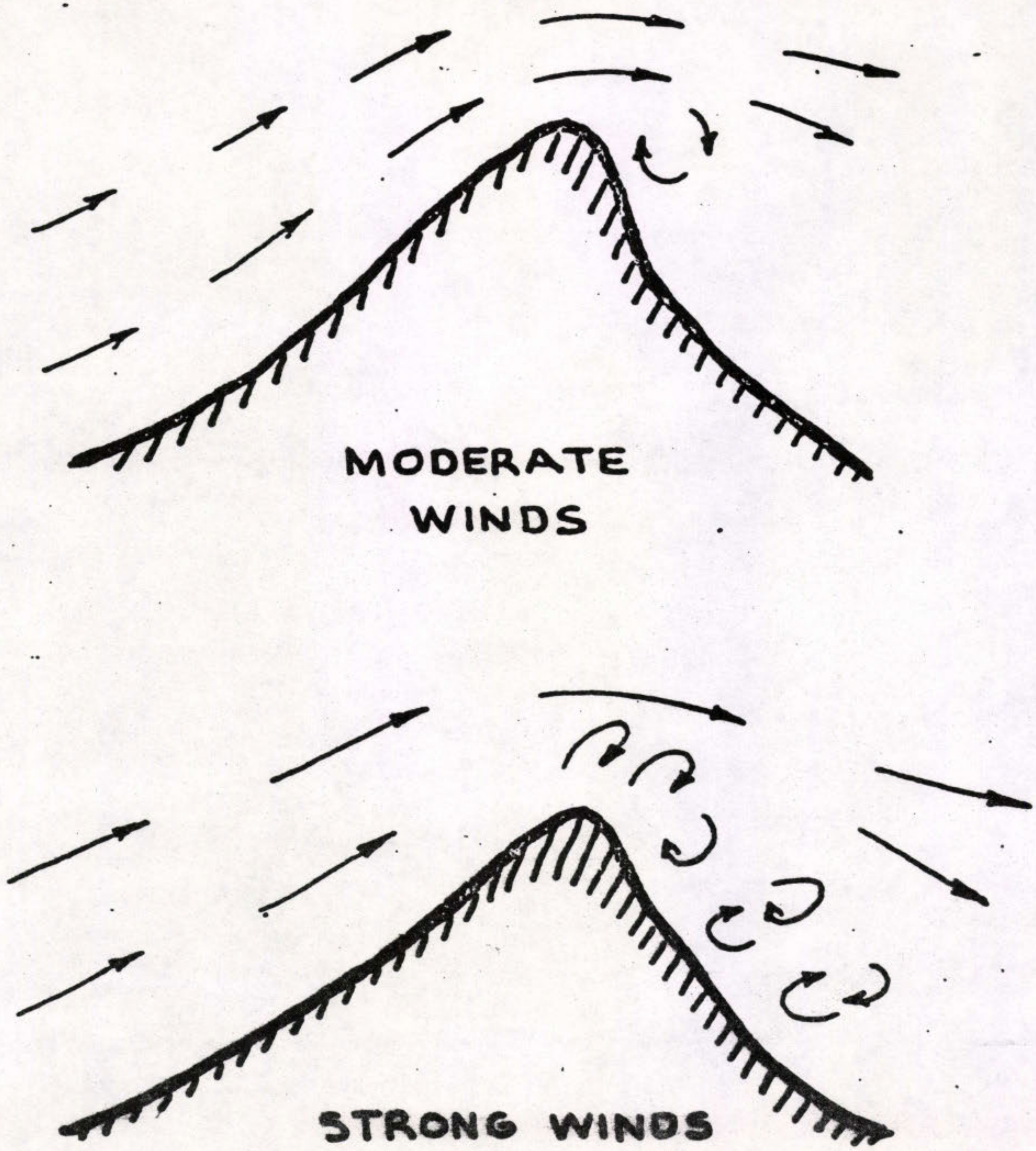
ROTATION OF SLOPE WINDS IN TWENTY-FOUR HOURS



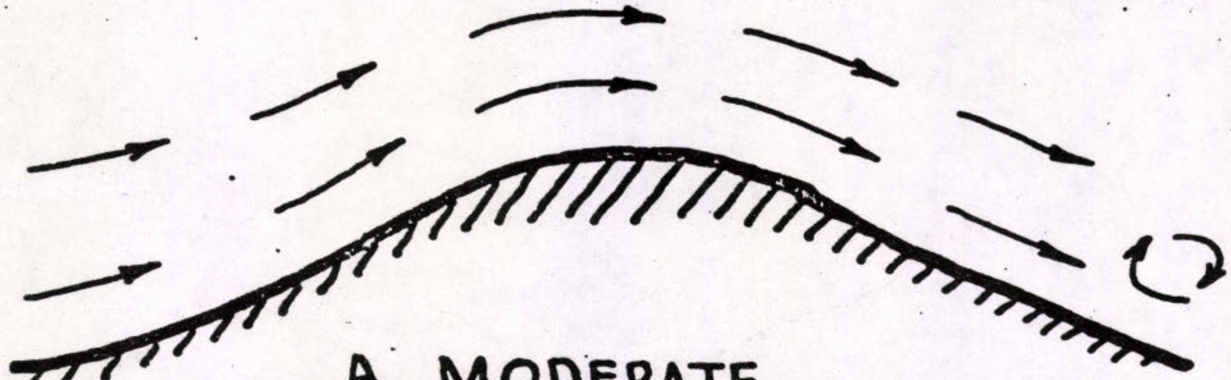
16a


Thunderstorm
winds
Safe Area
FIRE

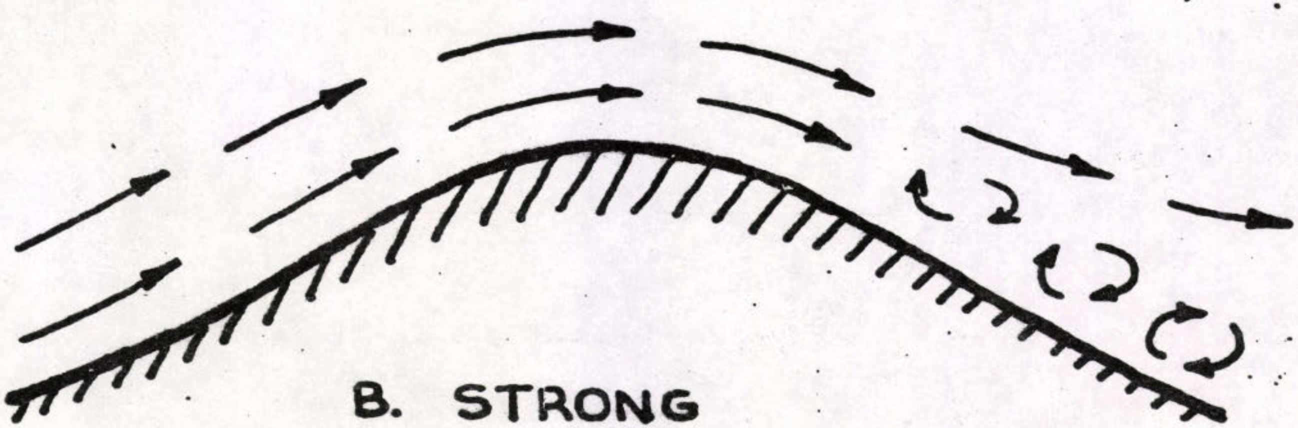
STEEP LEE SLOPE RIDGES



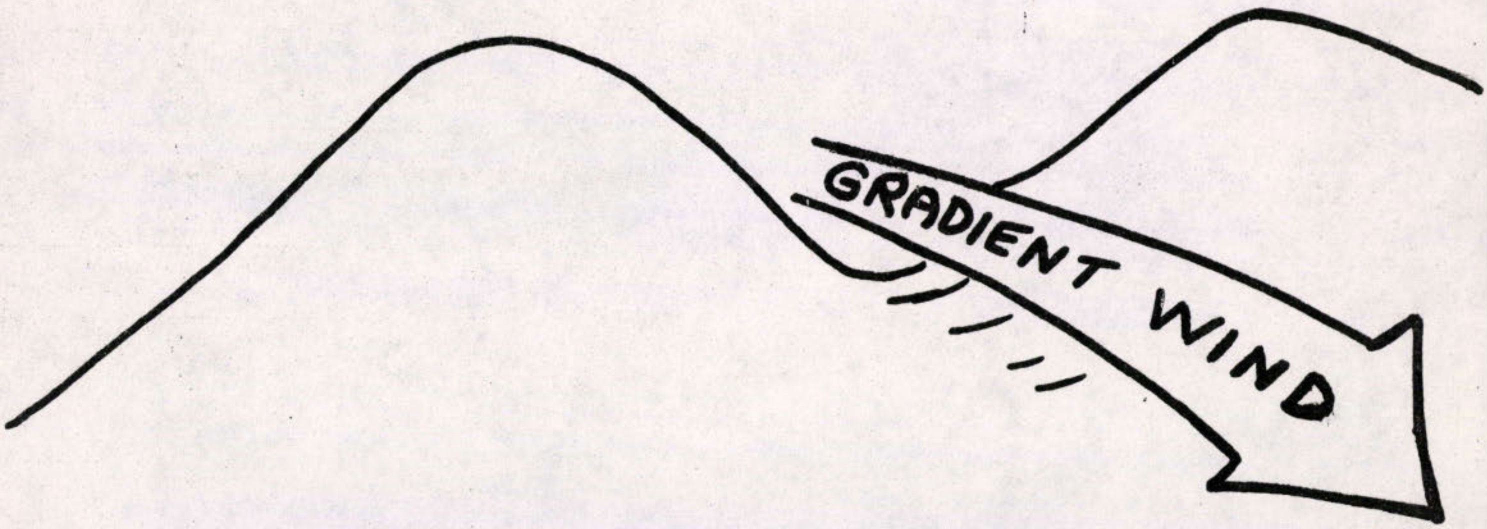
ROLLING TERRAIN



A. MODERATE WINDS



B. STRONG WINDS


GRADIENT WIND

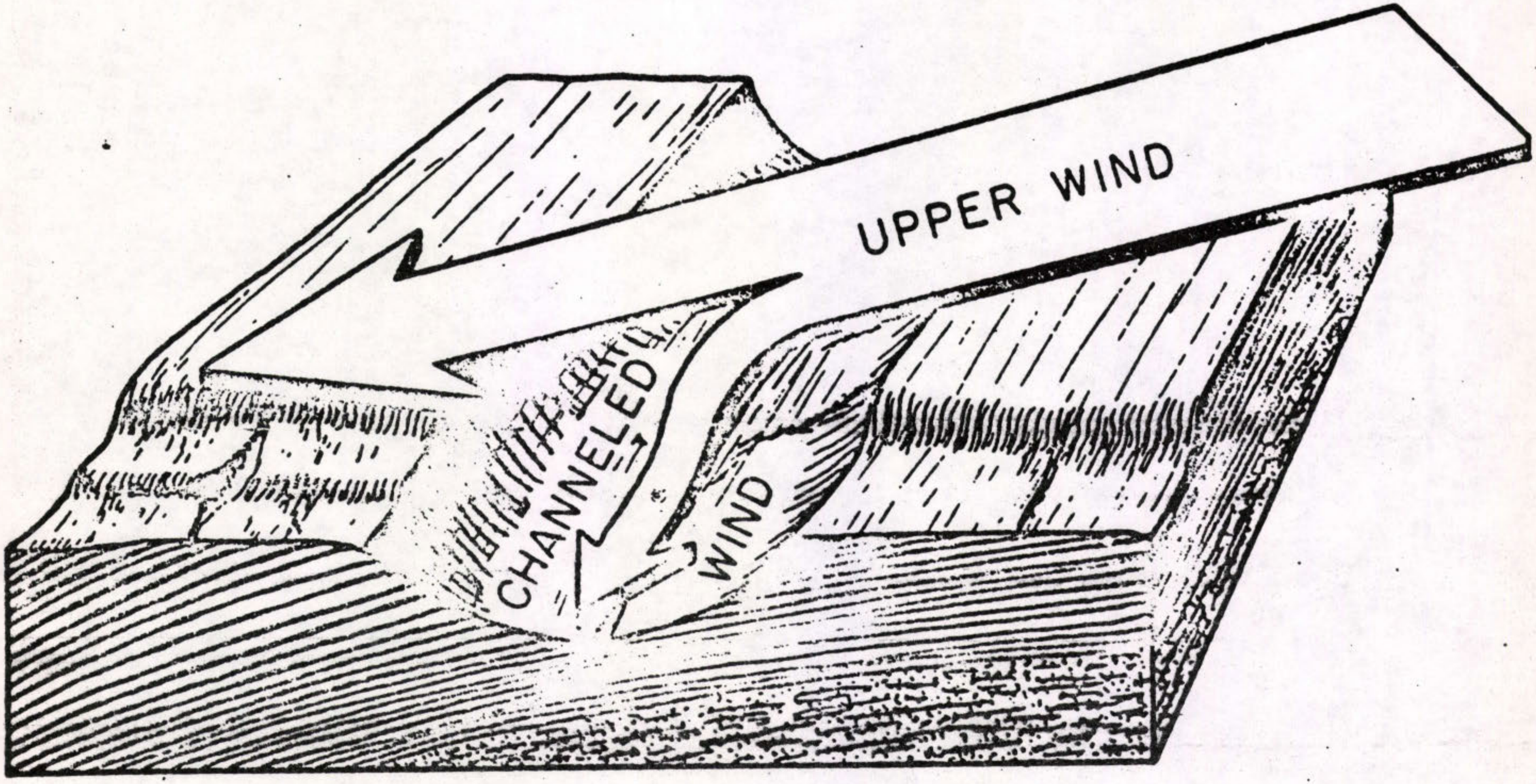
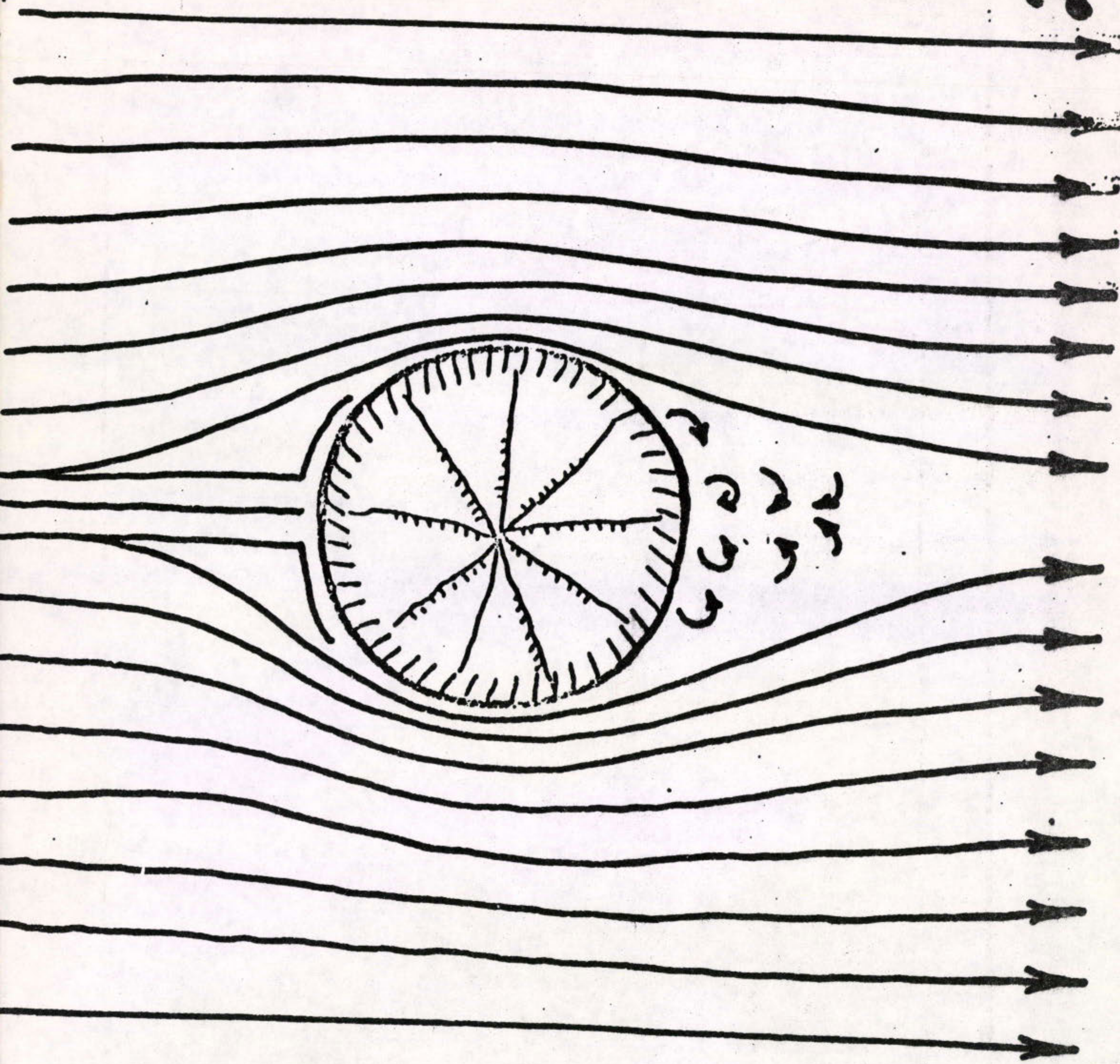
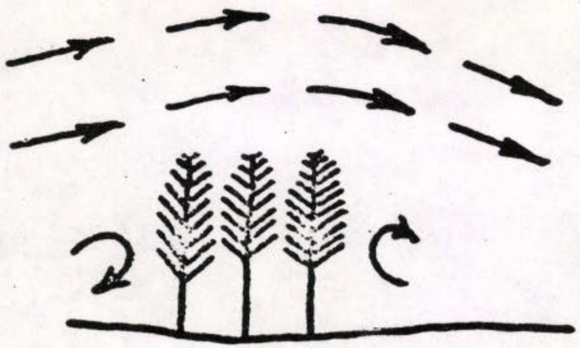
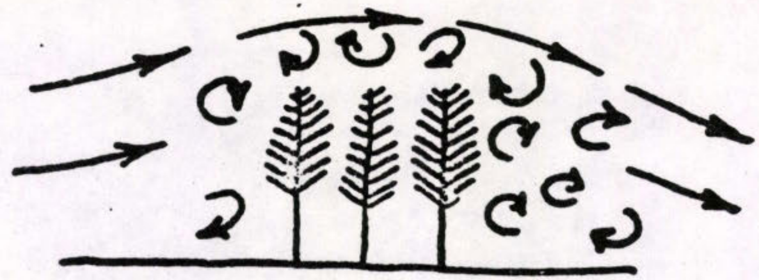


Fig. 3.3—Channeling of wind by a valley.

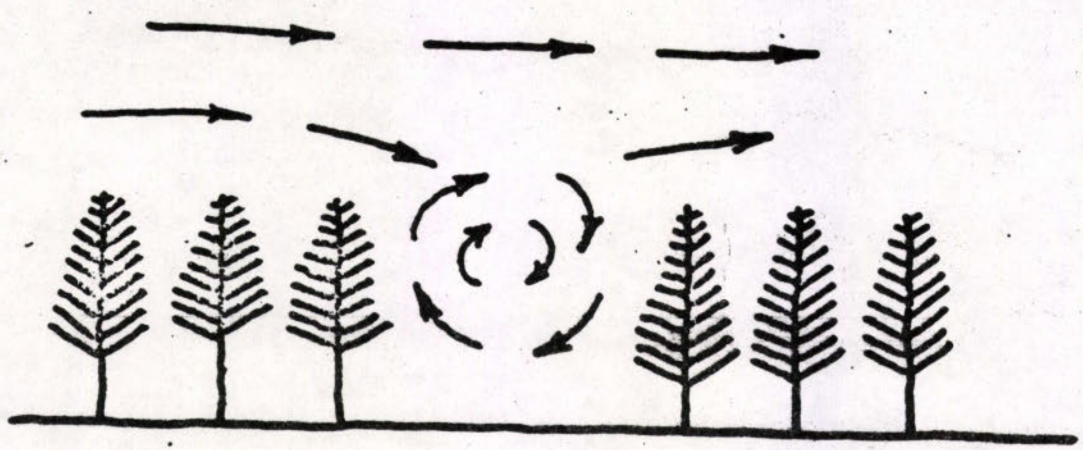




A.
LIGHT WINDS



B.
STRONG WINDS



BLUE

U. S. DEPARTMENT OF AGRICULTURE
Forest Service

INSTRUCTOR'S LESSON PLAN

SUBJECT: Fire Behavior	INSTRUCTOR: E. M. "Sonny" Stiger
TITLE OF LESSON: Fuels and Fire Behavior	FILE NO:
	DATE: 3/17/71
LENGTH OF LESSON: 2 hours and 10 minutes	NO. ASSISTANTS: None

METHOD OF INSTRUCTION: Lecture

PLACE: Rocky Mountain Forest and Range Experiment Station

TRAINING AIDS: Overhead projector, slides IV A (1) thru (8), Flip chart, carousel slide projector

NUMBER IN AUDIENCE: 50-60

OBJECTIVE: Trainees will learn to recognize fuel characteristics that influence fire behavior and be better able to predict fire behavior of fires burning in various fuel complexes.

TIME	LESSON OUTLINE	AIDS & CUES
1420	INTRODUCTION	

The title of this lesson is fuels and fire behavior.

What aspect of fuels do you look for when you arrive at the scene of a fire? Since you people have been on fires, or you wouldn't be here, you have sized up the fuel situation possibly without realizing it.

Let's take a hypothetical case to illustrate this point: You arrive at a fire, it is burning hot, the temperature is about 85°, relative humidity about 10%, the slope is 45°, the last weather forecast was for continued hot and dry.

Would you sound the general alarm before first considering the fuel situation? No. What if the fuels were so scattered that heat or flame would not possibly spread from one fuel patch to the next.

But under the same conditions it would be an entirely different story if the fuel was continuous.

Fuels must be sized up so that you can better determine the number of men needed, the kind and amount of equipment needed, the placement of your men and equipment, as well as the safety of your people.

You have done this instinctively, but now we want to look at the WHY of fuels and relate it to your common sense and practical application on the ground.

TIME	LESSON OUTLINE	AIDS & CUES
	The first thing you think about on a going fire is getting the men and equipment in to put the fire out. You must size up the entire fire problem. Fuel is just one facet of the problem. With this discussion on fuels, I hope to make this facet of the problem even more instinctive in your judgement.	
	Just about everything we're going to talk about can be evaluated by using horse sense, but errors in judgement can be costly, and even more important, <u>dangerous</u>. I was impressed at the school in Marana by the rather insignificant fire situations that resulted in deaths of fire fighters. It brought home the point to me that we must get this fire behavior knowledge down to the crew bosses.	
10 min.	Relate the case of 10 "Hot-shot" crew members burned to death on Loop fire in California and how this relates to fuels.	
	So what do you look for concerning the fuel situation so that you can: 1. Base all actions on current and expected behavior of fire, and 2. <u>Have escape routes for everyone</u> and make them known.	

TIME	LESSON OUTLINE	AIDS & CUES

DEVELOPMENT

Forest fuels, in general, do not change over long periods of time, except by timber harvest or fire, or other catastrophe, such as a four lane highway. Any given area will have much the same fuel each fire season. Any change in the overall fuel complex will be very gradual.

During the course of a year, however, the individual fuel properties will change with the seasons, due to the changes in weather. Even this change will be much the same from year to year.

Fuels of the same general type will have different characteristics from place to place. In a fuel such as forest litter, no two square feet will be alike either up and down (vertically) or across (horizontally).

Many of the problems of predicting forest fire behavior come from being unable to really measure and understand the variable characteristics of forest fuels.

1. Fuel Type Classification

First, let's discuss the only real measure we have and its weaknesses, then relate fuels to the principals we can understand and apply to practical situations.

Flip chart No. 1 Fuel type map of District.

You are all familiar with fuel type classification. In order to better understand and better relate fuels to each other it is necessary for us to classify or type them.

We do this by estimating the rate of spread of a fire through the fuel and the resistence of the fuel to control of a fire burning in it.

This classification is based on the average worst burning conditions (a hot, dry, breezy, late summer afternoon) is assumed. Effects of topography is not considered at this time.

Four classes are used for rate-of-spread and resistence to control. Low, Medium, High and Extreme.

TIME	LESSON OUTLINE	AIDS & CUES

Grass, for instance, would be rated EL for extreme rate-of-spread and low resistence to control.

A slow burning fuel but difficult to control would be rated LE or low rate-of-spread and extreme resistence to control.

A medium burning fuel MM, etc.

This is useful in fire control planning but it has many weaknesses when you have to predict the behavior of an individual fire.

1. The rate of spread and resistence to control do not always change alike when burning conditions change from the assumed conditions (The hot, dry, summer afternoon.)

2. Small areas in a general fuel type may vary widely from the over all classification.

3. Seasonal and daily changes may cause a fuel to differ from the previously assigned type classification.

So if we are going to try to predict the behavior of a fire, whether a wildfire or a prescribed burn, we need more specific information about fuels than the fuel type will give us.

You want to know how a particular fuel complex on fire will behave on a given day under given conditions, That fire on that day will depend on previous and current fire weather, topography, slope, aspect, etc.

TIME	LESSON OUTLINE	AIDS & CUES

2. Fuels and Rate of Spread

Let's study more specifically, fuels and related rate of spread.

In order to plan your control actions you want to be able to estimate how fast a fire will spread. We are not going to discuss weather and topography, important as these influences are, but rather, strictly the relationship of fuel to the rate of spread.

A. Size

We know that a fire will start more easily in small fuels. The rate of spread is also faster in small fuels. You know this, but why is it faster? The smaller the fuel the more surface area it has to dry and gain heat. Larger fuels dry more slowly and stay relatively cooler. *So - the size of the fuels affect the rate of spread.

Flip chart No. 2 Ease of ignition small and large fuel.
*Overhead projector slide IV-A (6)

Therefore, we can say that the spread of surface fires is largely a factor of the presence of fine, flashy fuels that can be ignited readily and release heat rapidly. Or, put another way, the rate of energy released is rapid.

B. Arrangement

But, although a fuel may be of a size for fast burning, the way it is arranged may counteract this.

What do we mean - arrangement?

Closely packed fuels may keep air from getting to the fire and consequently the fire will burn more slowly. The old fire triangle.

Conversely, if a larger, slower burning fuel is spaced (or arranged) so air can readily get to it and yet individual fuel pieces are close enough together so that heat from one piece will easily ignite another, the fire may spread faster than in smaller but more densly matted litter and duff.

You have all seen how smoldering litter when fluffed up quickly ignites into flame.

TIME	LESSON OUTLINE	AIDS & CUES

QUESTION: In light of the above, will newspaper burn faster than dry boards under equal conditions of moisture?

ANSWER: It depends on the arrangement and relative compaction of each.

Relate the analogy of Storm Mountain cabins where after all had burned a tightly rolled bundle of newspapers still remained with only the outside layer scorched.

Fuel spacing or arrangement also effects the heat transfer process. The more closely spaced the fuel is, the harder it is for convection transfer of heat.

The wind or draft cannot bend the flame through the fuel bed to reach new fuel.

We can say then that the arrangement or spacing of the fuels affects:

(1) Oxygen supply
(2) Availability of new ignitions, and
(3) The heat transfer process
AND
Consequently, the rate of spread.

C. Fuel Moisture Content

Fuel moisture content is perhaps the most controlling on the rate of spread and ease of ignition.

It is expressed in percentage, computed from the weight of contained water divided by the oven dry weight of the fuel.

*Atmospheric moisture is a key element in fire weather and it has a direct effect on the flammability of forest fuels through fuel moisture.

*Flip chart No, 3 Figure 4, page 42.2--2 Firemans HB

TIME	LESSON OUTLINE	AIDS & CUES
	Prolonged periods with lack of clouds and precipitation (both seasonal and over several years) set the stage for severe burning conditions by, 1. increasing the availability of dead fuels and, 2. depleteing soil moisture, necessary for the normal physiological function of living plants and, thereby, the fuel moisture in both dead and living plants.	
	Severe burning conditions are not erased easily. Extremely dry forest fuels may undergo superficial moistening by rain in the forenoon, but may dry out quickly and become flammable again during the afternoon.	
	By the same token, the reverse is true in that prolonged periods of cloud cover and moisture both seasonal and over several years has the reverse effect on fuel moisture.	
	*Let's look at some seasonal fuel moisture variations.	*Flip chart No. 4 Page 191, Fire Weather HB 360.
	Forest fuels which are wet may burn if enough heat is applied, but generally the fire will not spread far or fast.	
	We know this, but WHY?	*Overhead projector slide IV-A (7)
	It is nearly impossible for the fire to generate enough heat to both turn the water held in the fuels to steam, plus heat the fuels sufficiently for the necessary vapors and gases to be given off and ignited. In this process the steam given off may be enough to smother the fire.	
	Fuel moisture also determines fuel availability which we will discuss later.	
	*As dead fuels dry from the time they were last wetted, the fine fuels dry first, often in hours or even minutes.	*
	The small fuels, such as tree limbs and the stems of brush dry at a slower rate than fine fuels.	
	The larger fuels (large limbs, logs, etc.) take much longer to dry.	Flip chart No. 5 Page 193 Fire Weather HB 360.

TIME	LESSON OUTLINE	AIDS & CUES

Let's discuss this in terms of what it means to you. Remember we relate fire danger, or burning index, to average worst burning conditions. We take the fire danger reading at 1300, but* look at how it varies on a typical mid-summer day.

*Fuel moisture is an integral part of your fire danger computations.

When you estimate the behavior of a specific fire, you should relate the fire danger reading (burning index and spread index) measured at the fire weather station to the probable index at the site of the fire.

Under critical fire weather conditions, it is often adviseable to measure fire danger at more than one time during the day.

Fires in different fuel types will necessarily then behave differently at different times of the day.

Fires in flashy fuels, such as dry grass, will begin to spread rapidly at a much lower fire danger and earlier in the day and season than in heavy fuels.

Once the fine fuels have dried sufficiently for fire to burn them readily and they are ignited, they will provide heat which will dry the small fuels.

The small fuels are then ready for ignition and spread of fire and the process continues on through the larger fuels.

You have realized this principal many times. Why do you instruct your nozzel men to direct the spray at the base of the tree or at the smaller fuels underneath the larger logs? Not because the smaller fuels are the only ones burning at the time, but because by dousing these fuels you have eliminated the heat source that would eventually or maybe has already started to ignite the large fuels.

AIDS & CUES:

*Flip chart No. 6 Fig. 26, page 42, Fire behavior in Northern Rocky Mountain Forests.

*Flip chart No. 7, page 192, Fire Weather HB 360.

TIME	LESSON OUTLINE	AIDS & CUES
	As stated, outside of actual precipitation, the moisture in the air is the main factor controlling fuel moisture.	
	Forest fuels absorb moisture from the air easily. The smaller the fuel the easier moisture is absorbed.	
	Fine fuels, litter, and grasses, for instance, change moisture content rapidly and in considerable degree when the air changes from dry to moist and vice versa.	
	*In contrast the moisture content of large fuels vary slowly and in lesser amounts with changes in air moisture.	*Flip chart No, 8 page 190 Fire Weather HB 360
	Therefore, this important principal. Since the fine fuels present in an area largely control the spread of fire, and since the fine fuels are particularly responsive to changes in air moisture, it follows that air moisture and fuel moisture are important considerations to you in predicting the spread of the fire.	

TIME	LESSON OUTLINE	AIDS & CUES

D. Fuel Continuity

The amount of fine fuels. This leads us logically into the next facet of the fuel complex related to rate-of-spread.

I have often felt that the reason we do not have large conflagrations on the eastern slope in this area is because we lack the abundance or continuity of grass and under growth such as in the Black Hills and other parts of the region.

You should then size up fuel continuity and quantity of both large and fine fuels when you arrive at a fire, whether as initial attack or on your sector or division on a large fire. This, we will look at next.

As we have indicated, continuous easily burnable fuels will spread rapidly and heat the larger fuels to ignition temperature. Nothing illustrates this better than a fire burning in slash when burning conditions are right and the slash is uniform and continuous over the area.

On the other hand, fire in highly burnable fuels occuring in patches and separated by fuels such as green grass or green brush will not spread rapidly from patch to patch.

If the connecting fuels were dry grass and dry brush the fuel available to the fire would be continuous and rapid spread would result.*

*Overhead projector slides IV-A (2) & IV-A (3).

We must also consider the continuity between ground fuels and aerial fuels.

Easily burnable ground fuels in forest areas in which there is a clear break between ground and aerial fuels are not as dangerous as smaller amounts of ground fuels where the fuels are a continuous bridge up into the crowns of the trees.*

*Flip chart No. 9 depicting relationship between ground and aerial fuels.

We can say then that even easily burnable fuels need not concern you as much if they are not continuous.

TIME	LESSON OUTLINE	AIDS & CUES

E. Fuel Quantity

It is difficult to classify and measure in a way that would help us in fire control, the quantity or amount of fuel in any given area. This factor is extremely variable.

First of all, you run into how much of the fuel on an area is available for combustion.

Available fuel is the quantity of fuel that actually burns in a forest fire.

The amount of fuel available for combustion is often determined by interior moisture gradients.

What is a gradient?

Simply a difference expressed as a rate of change.

There is one moisture gradient between the fuel and the air, another between the fuel and the soil, and still another between the top and bottom of the fuel bed itself.

This determines fuel availability aside from the actual physical quantity.

In some cases, for example, fire may only skim lightly over the surface; in others, the entire dead fuel volume may contribute to the total heat output of the fire.

*Let's look at this slide of the fuel components. — *Overhead projector slide IV-A (1)

It appears that the quantity of fuel is high, but remember that even in fuels of the same total amount, the quantity of available fuel will vary widely due to differences primarily in fuel moisture.

Here again, we must go back to fuel moisture. If the fuel moisture content were low this entire fuel complex might be available for combustion which makes the quantity of fuel available much more than if the fuel moisture were high.

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	You can be confronted with any combination of these fuel components that will make up varying degrees of physical fuel quantity.	
	Therefore, with all of the many and varied factors we have dicsussed comes the difficulty in pre-classifying and mapping amounts of fuel so you can have a ready reference when a fire report comes in.	
	How much is there?	
	It depends upon how much is available to burn at any given time.	
	Total dry fuel weight per unit of area is possible but expensive, to obtain and it is only menaingful when it is related to some classification by fineness, compaction, location and arrangement. *	*Overhead projector slide IV-A (8)
	These factors of quantity are very hard to express in units of weight or volume.	
	But you've got your eye and brain, which combined, make up a pretty good computer of the way a certain fuel on fire will behave under certain conditions.	
	The next time you go into the field don't just look, but see what we have been talking about.	
	Most of you can study areas, in fuel types with which you are familiar and give a relative indication of fuel quantity, such as, this place has more fuel than that place, and the more fires you have seen burn in particular fuel types the better your judgement will become on the effect of fuel quantities on fire behavior in each fuel type under varying conditions of weather and topography.	
	Generally, we can say that the more dead, dry, fuel on an area, the more intense the fire, the more fuel that will become involved (available fuel) and this will in turn, influence the rate-of-spread.	

TIME	LESSON OUTLINE	AIDS & CUES
	Up to this point we have discussed:	
	1. Fuel type classification and its weaknesses.	
	2. The relationship of the fuels to the rate of spread of a fire.	
	QUESTION:	
	What fuel factors, that we have discussed, relate to rate-of-spread?	
	a. Size of fuels	
	b. Arrangement	
	c. Fuel moisture	
	d. Fuel continuity	
	e. Fuel quantity	
1520	Do you have any questions concerning fuels and rate-of-spread?	
	STRETCH BREAK	

TIME	LESSON OUTLINE	AIDS & CUES
	3. <u>Fuels and Resistence to Control</u>	
	Let's now look at the relationship of fuels to resistence to control of a fire.	
	Resistence to control is affected by topography, ease of digging the soil and fatigue of fire fighters and/or breakdown of machinery.	
	We are only concerned with the fuel factors in this particular presentation.	
	A. <u>Fire Intensity</u>	
	You have all had the experience of trying to fight a fire that was spreading rapidly through heavy, fast burning fuels and not being able to work close to the fire because of the heat.	
	This experience certainly illustrates that the intensity of a fire, <u>which is directly related to the fuels available to the fire</u>, is a major factor in the resistence to control of a fire.	
	Fire intensity can be described as the amount of energy produced per unit of line. Current fuel moisture and cumulative seasonal fuel drying are closely correlated to fire intensity.	
	Fires burning in light fuels do not build up a great deal of heat and, other factors being equal, will have a low resistence to control.	Carousel projector slide 1.
	You have worked on fires in cheat grass or other fuels where you could scratch in a very narrow line right next to the fire edge and effectively stop the spread.	Carousel projector slide 2.
	You have also worked on fires in heavy fuels, such as logging slash, or even light fuels such as dense brushfields, where the fire was so intense that it was necessary to build the control line back away from the fire edge and burn out or possibly back fire to keep the intense heat of the fire away from the control line.	

TIME	LESSON OUTLINE	AIDS & CUES
	Anytime a factor of fire behavior dictates to you a course of action, then it becomes pretty important. Therefore, <u>fire intensity</u> becomes one of the more important factors you must consider in predicting fire behavior and planning control of a fire.	
	B. <u>Fire Persistence</u>	
	Fire persistence is related to fire intensity. What is it? In the cheat grass example there is a direct relationship between intensity and persistence.	
	Once the fire is cut off from new fuel it dies out quickly, <u>in other words, it does not persist.</u>	
	But, you can all think of other low <u>intensity</u> fires which are quite persistent, such as fires in rotten forest litter or fires in saw dust piles.	
	The intense fire in heavy slash would be very persistent due to the la rge amount of fuel available after the fire is cut off from new fuels.	
	Think of the grass fire that burns out almost immediately, then think of the slash fire that can burn for days causing many days of mop-up after the fire spread is controlled.	Carousel projector slide 3. slide 4.
	This persistence then is a factor of fire behavior prediction that you must allow for and evaluate closely.	
	A persistent fire presents a constant threat of ignition of new fuels.	
	A brush field fire of high intensity presents a different problem. While the fire may be intense, depending upon fuel moisture, etc. , it dies down rather quickly when it is cut off from new fuels, but the fire may have only burned off the leafy fuels and in the process dried the stems and branches so that the brush field is ripe for a reburn.	

TIME	LESSON OUTLINE	AIDS & CUES
	This, then is a different type of fire persistence. You can probably think of other examples of fire persistence.	
	C. Physical restrictions	
	Fuels have another obvious effect on resistence to control.	
	This is their physical size, arrangement, continuity and quantity which directly affect the ease of control line construction.	Carousel projector Slide 5.
	Fine fuels such as grass and litter are generally easy to build control line through, while larger fuels like brush and small trees are tougher, logs and snags, tougher yet, and are probably the most difficult fuels to build fire line through.	Slide 6
	But remember that these general observations are always modified by the arrangement, quantity, continuity and complexity of the fuel bed.	
	I've discussed three primary ways that fuels affect resistence to control.	
	GUESTION:	
	What are these three ways?	
	(1) Intensity of the fire.	
	(2) Persistence of the fire.	
	(3) The amount of direct resistence of the fuels to line construction.	

TIME	LESSON OUTLINE	AIDS & CUES
	4. <u>Special Fire Behavior Factors in Fuels</u>	
	A. <u>Fuels and Crown Fires</u>	
	So far we have been relating most of our discussion to surface fires.	
	But, all of the fuel factors that affect surface fires are significant in the behavior of crown fires as well.	
	In most cases, crown fires stem from initial surface fires and in most cases depend on surface fire below for any sustained runs.	
	Fuel conditions which give hot surface fires are, therefore, the first key to potential crown fire development.	
	Let's define crown fire right now.	
	<u>CROWN FIRE</u>: A fire that advances from top to top of trees or shrubs more or less independently of the surface fire. Sometime crown fires are classed as either running or dependent, to distinguish the degree of independence from the surface fire. See "Crown Out".	Carousel projector slide 7.
	<u>CROWN OUT</u>: Fire burning principally as a surface fire that intermittently ignites the crowns of trees or shrubs as it advances.	Slide 8.
	Let's differentiate between these two in our radio conversations on a fire.	
	In order for the fire to get into the crowns, it is necessary for the fire to heat the fuels in the crowns to ignition temperature. Since the temperature of the convection column of the fire drops quite rapidly above the flame zone, we can see that there must be a very intense or a very persistent surface fire to develop the necessary heat.	
	Small openings in continuous canopies are sometimes the beginning place for crowning. They provide natural chimneys that may accelerate the burning rates of surface fires spreading into them. The trees around these openings often have both full crowns and lower limbs which are closer to the surface fuel.	Flip chart No. 10 opening in canopy actual chimneys.

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	The more continuity there is between the ground and aerial fuels the less heat is needed to bridge the gap. This is <u>vertical continuity</u>. Whether a forest canopy is open or closed has a definite bearing on whether a crown fire will spread. This is <u>horizontal continuity</u>. But a closed canopy will generally keep surface fuels more moist and cooler than that which is exposed to the sun. Surface fires will burn with less vigor under a closed canopy given the same conditions otherwise than a surface fire will burn in the open under an open canopy. While the surface fire will burn more vigorously under the open canopy, the tree crowns may not be close enough for the fire to travel from one to the other and an open canopy will also allow more wind to reach the surface fire, bending the flames away from the tree crowns. To support a crown fire then, we can say that a canopy open enough to permit appreciable wind to blow through the canopy and yet dense enough to support continuous flaming without repeatedly dropping to the ground, is needed. Look 'em over then on the next fire and evaluate this potential. The next lesson on topography will cover effects of slope on sustaining a crown fire. But it should be pointed out that under severe weather conditions, a crown fire can develop on relatively flat ground and even downhill. (If time allows, relate the Pass Creek incident.)	Carousel projector Slide 9. Slide 10.

TIME	LESSON OUTLINE	AIDS & CUES
	B. Fuels and Fire Spotting	
	Most fuels will produce embers capable of starting spot fires under the right conditions, BUT, there are some fuel distinctions that we should make.	
	Flash fuels are usually limited to only short distance spotting because they burn up and cool quickly.	
	Larger embers burn for longer times with flame or glow, but as size increases so does weight. The heavier the embers the less chance of them being carried through the air.	
	The most likely materials for distant spotting are either exceptionally low in density, (such as rotton wood and bits of bark of some specie) or shaped with airfoil characteristics enabling them to sail when air borne (such as leaves and, again, some bits of bark of other specie.)	Flip chart No. 11 Spotting materials.
	The nature of the fuel on which the embers land and the moisture content of those fuels is one of the major factors affecting the start of spot fires.	Flip chart No. 12 Fine fuel moisture related to spotting
	We can probably say that most spot fires are started by smoldering or glowing, rather than flaming embers.	
	This means that we can expect spot fires to start in fuels which ignite by conduction, such as rotton wood and duff.	
	Snags are both prolific producers of spotting embers and frequent receivers of them. This you know from experience, and it should be pretty clear what your actions should be when confronted with snags on a fire.	

TIME	LESSON OUTLINE	AIDS & CUES

5. Fuels and Fire Control Planning

Let's consider now the effects of fuels on fire control planning.

When we make plans for protection of an area from fire, we think primarily of two things,

1. The risk of occurance of a fire, and,
2. The probable size a fire is apt to become under varying conditions once it is started.

The fuels then in the planning area become an important factor.

When you examine the fuel of an area for risk of fire starts, it is usually advisable to consider the types of fire brands it is likely to be exposed to.

Rotton logs, rotton stumps and exposed lower duff are likely starting points for fires from hot objects. They do not have to be flaming. (Such as pipe heels or carbon sparks and possibly even defective mufflers.)

Litter and standing grass are more likely to be ignited by flaming objects.

The fuel surface temperature and dryness determine the ease of ignition for both hot and flaming objects, but surface temperature is less important in the case of the flaming fire brand.

A review of statistics of large numbers of fires show that the greatest number of fires occur in fuels which are classed as flashy, for the reasons we have discussed.

When we consider the size of a fire in relation to the fuel it occurs in, we find that there is less difference in the size of a fire from discovery to control in fuels with low rates-of-spread than a high-rate-of-spread.

*In other words, the biggest fires occur in fast spreading fuels. — *Flip chart No. 13.

Now, let's make an obvious deduction from statistics that the most dangerous and destructive fires generally occur late in the fire season, due to the progressive drying of forest fuels.

TIME	LESSON OUTLINE	AIDS & CUES
	*The burning index is an indication of this seasonal drying.	*Overhead projecto Slide IV-A (5)
	*This slide indicates the precent of fires reaching class C or larger size according to material first ignited.	*Overhead Projecto Slide IV-A (4)
	At first glance it would tend to contradict some of the basic principals we have discussed.	
	But, upon further study you can see that it actually supports our conclusions.	
	For instance, fires starting in slash are more likely to create the la rgest fires.	
	Even more than those starting in grass.	
	Now some of the grasslanders might argue with you, but remember, this is overall averages.	
	We have **said** that the rate of spread will be greater in grass than in heavier fuels. <u>But</u> now you must begin to combine all of the principals discussed.	
	No. 1. In order for a fire to start in slash, it must be pretty dry and late in the season.	
	Therefore, if it is dry enough for the initial start to take place in slash you have a potentially serious condition on your hands right off.	
	No. 2. Remember arrangement, quantity of dead fuels and continuity.	
	Arrangement in slash fields are such that air can readily reach the fuels.	
	Quantity, depending upon the type of cut, you've got plenty of dead fuel - Fire intensity.	
	Continuity, in most cases the limits are the size of the cut over area.	
	With this in mind, I think the slide pretty well tells the story.	
	These considerations of the risk of ignition of fuels and effects the various fuel components we have studied have on the average size of fires, indicates where our efforts whould be directed in planning for fire protection.	

TIME	LESSON OUTLINE	AIDS & CUES

SUMMARY

We have discussed fuels and fire behavior at some length, emphasizing size, arrangement, moisture content, continuity, quantity and fire intensity and persistence related to ease of ignition, rate-of-spread and resistence to control.

Flip Chart No. 14 Listing of points covered.

We have discussed these factors from the standpoint of safety, proper utilization of manpower and equipment on going fires as well as in pre-attack planning.

I believe that you can more clearly see the complex nature and relationships between the many fuel components.

The forest officer concerned with prediction of the behavior of a going fire must consider many things about the fuel complex.

This will be you at one time or another whether you are in charge of initial attack, assigned a line position on a large fire, or as a line locator or scout.

You must do this based on your own experience or the experience of others in similar fuels. At the present time there are no systematic methods of measuring the fuel complex.

Forest officers with fire control responsibilities must depend largely upon their personal knowledge of these principals and good horse sense in order to predict how fuels affect fire in total, how they differ between each other and how they differ with time.

The faster the rate of spread and the greater the persistence the more men that will be needed to control the fire.

A high resistence to control will require different tools than a low resistence to control.

A high rate of spread and fire intensity in a particular fuel will have a bearing on whether you will employ direct or indirect control and where you will locate escape routes.

The many other combinations will require all of your knowledge of fuels to do the best job.

TIME	LESSON OUTLINE	AIDS & CUES
	Next summer, when the fires start, make a special effort to evaluate the fuels in the context that we have discussed and relate how the fire behaves to what you have learned.	
1620	As they say "THE LIFE YOU SAVE MAY BE YOUR OWN"	
1640	Questions?	

(FUEL TYPE MAP OF DISTRICT)

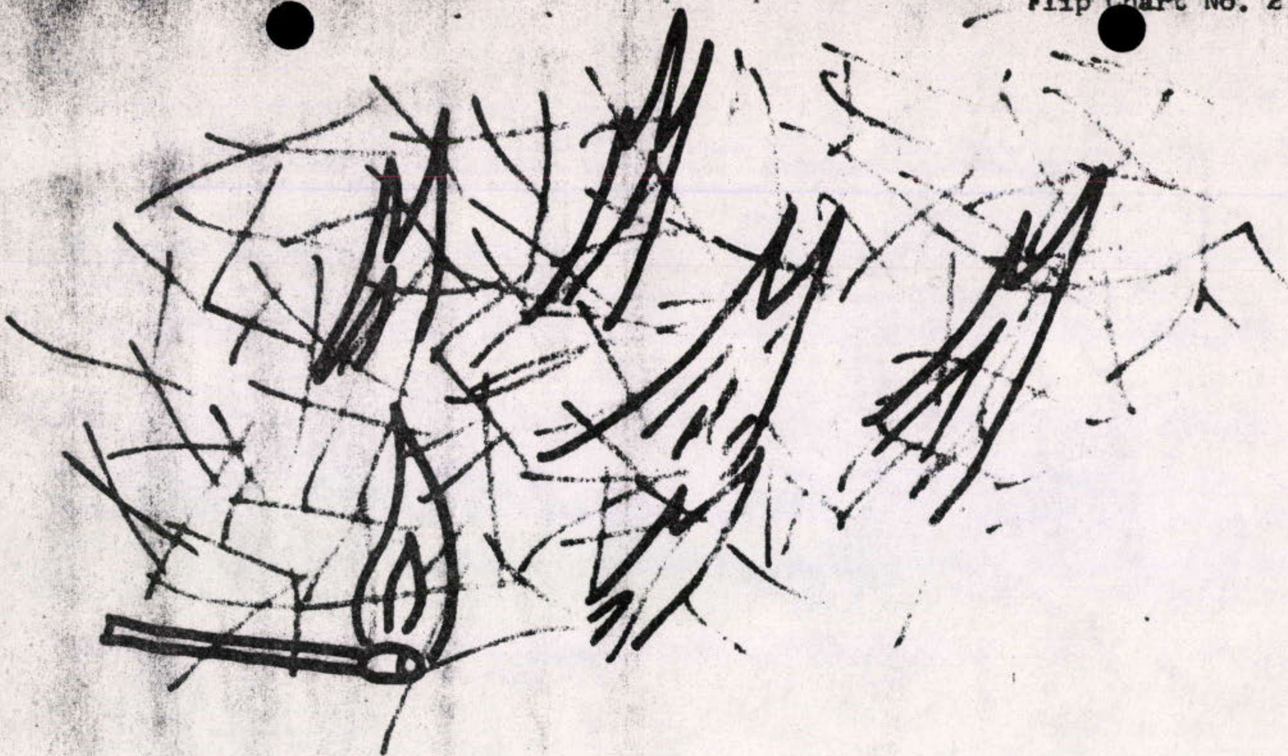
Rate of spread and resistance to control under average worst class of day.

1. Rate of spread (chains per hour)

Low	1 - 10
Medium	11 - 20
High	21 - 40
Extreme	41 plus

2. Resistance to control (chains per man-hour)

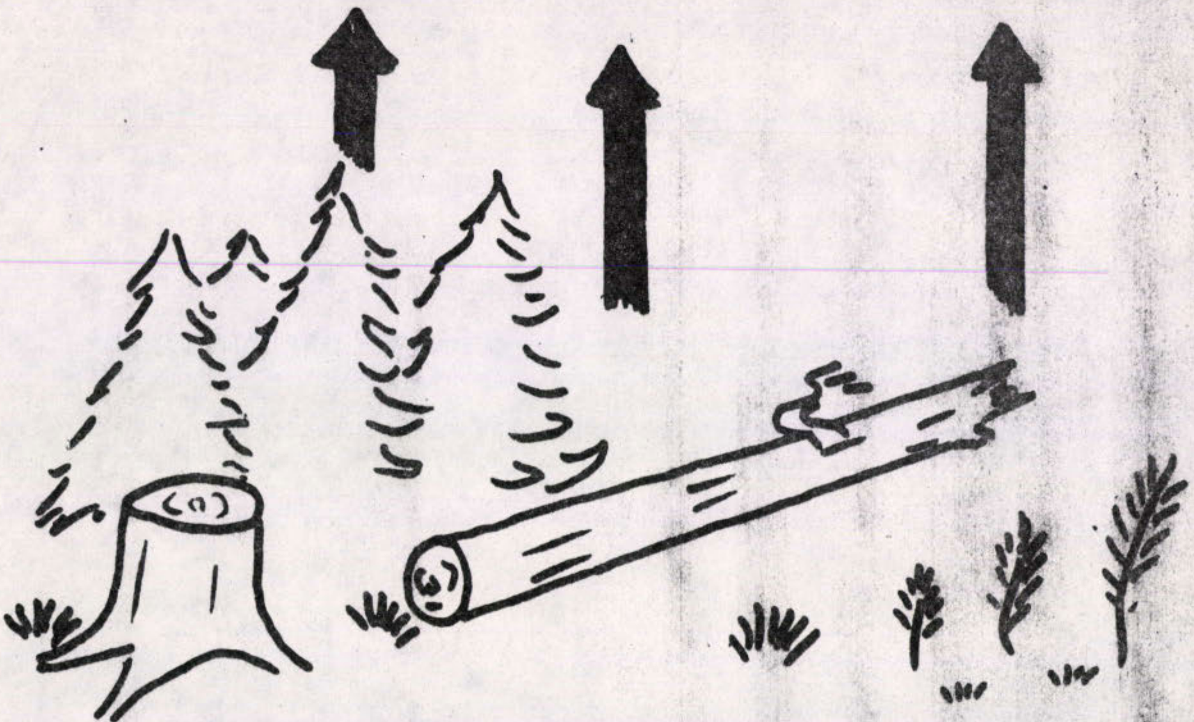
Low	5 plus
Medium	2.6 - 5.0
High	1.1 - 2.5
Extreme	1 or less



Easy ignition - rapid rate-of-spread

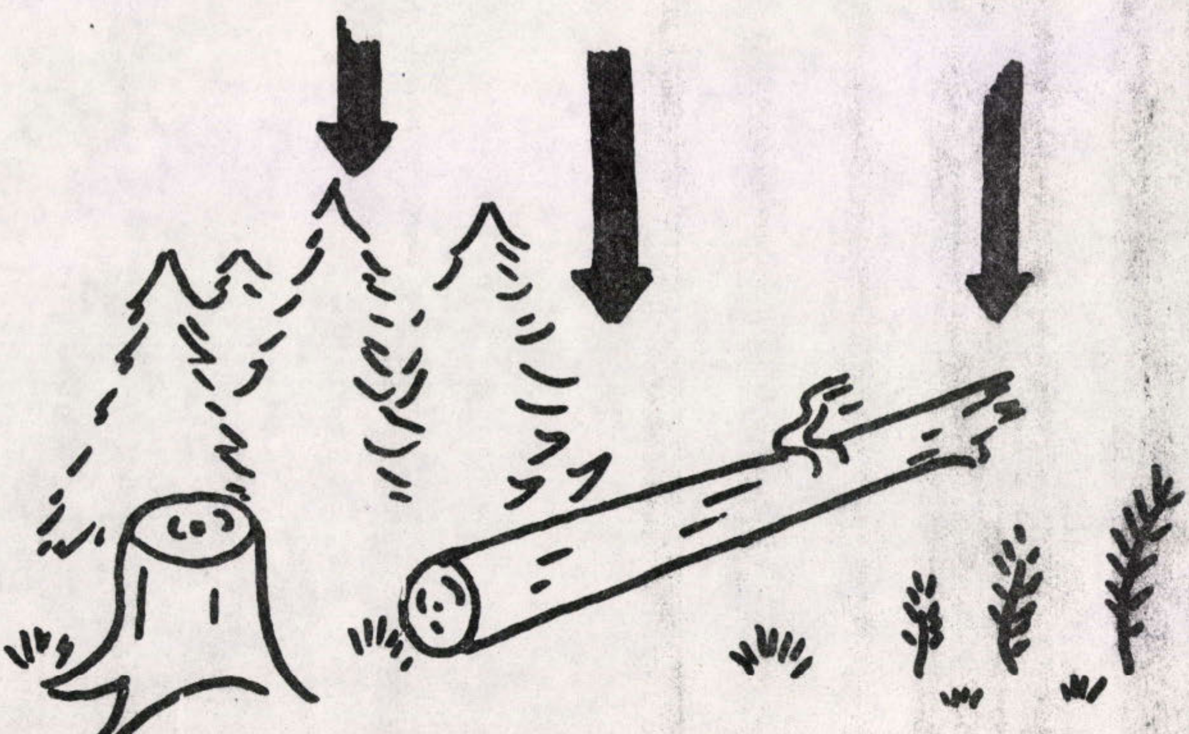
Hard to ignite - slow rate-of-spread

DRY AIR



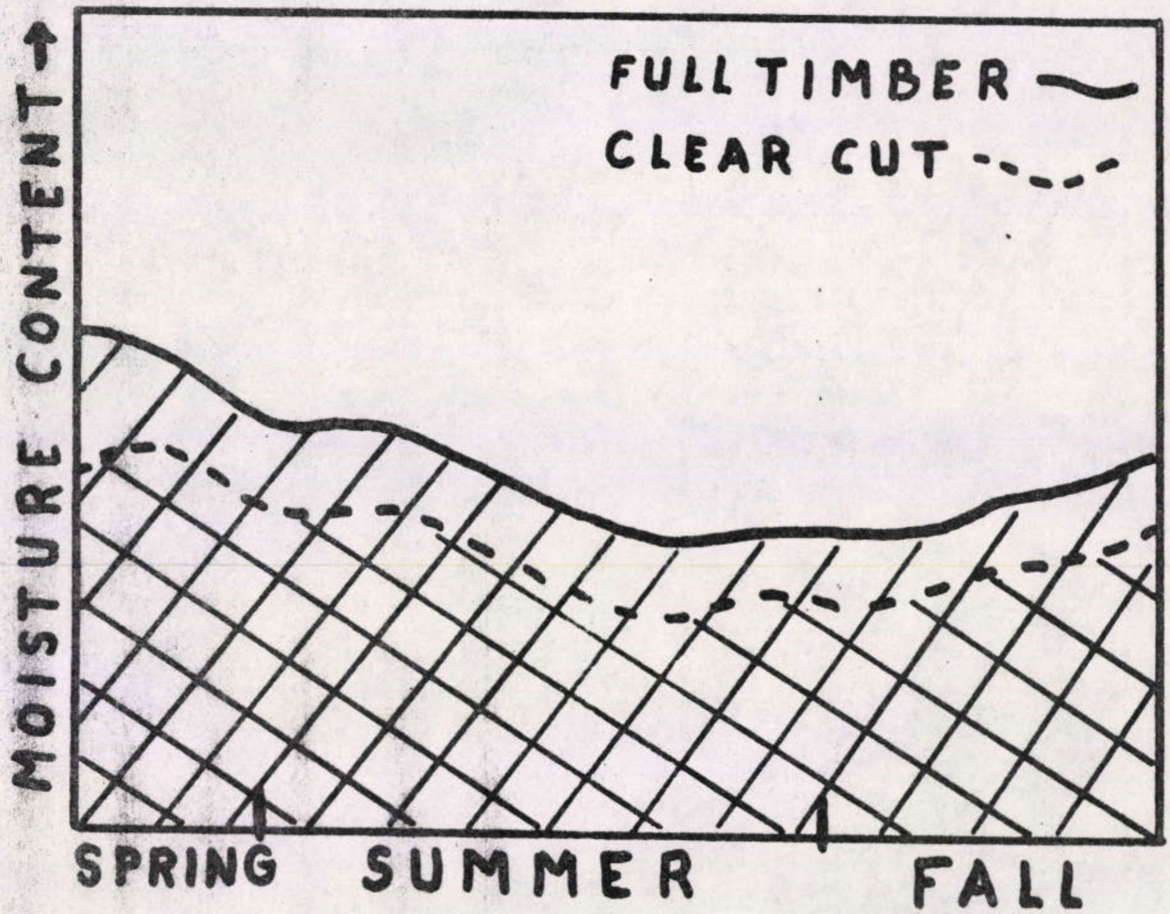
Dry air draws moisture from fuel.

MOIST AIR



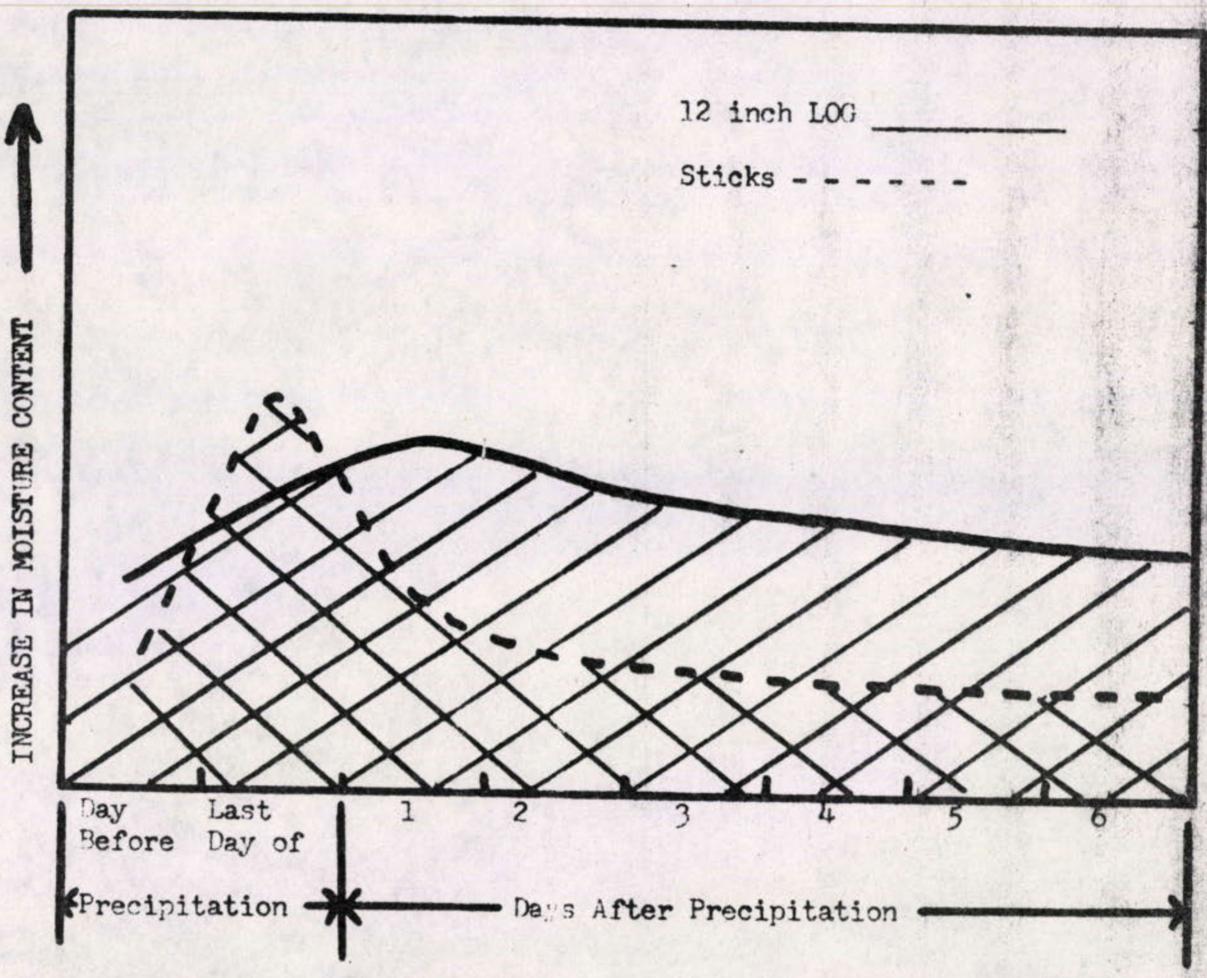
Fuels draw moisture from damp air.

SEASONAL VARIATION IN FUEL MOISTURE



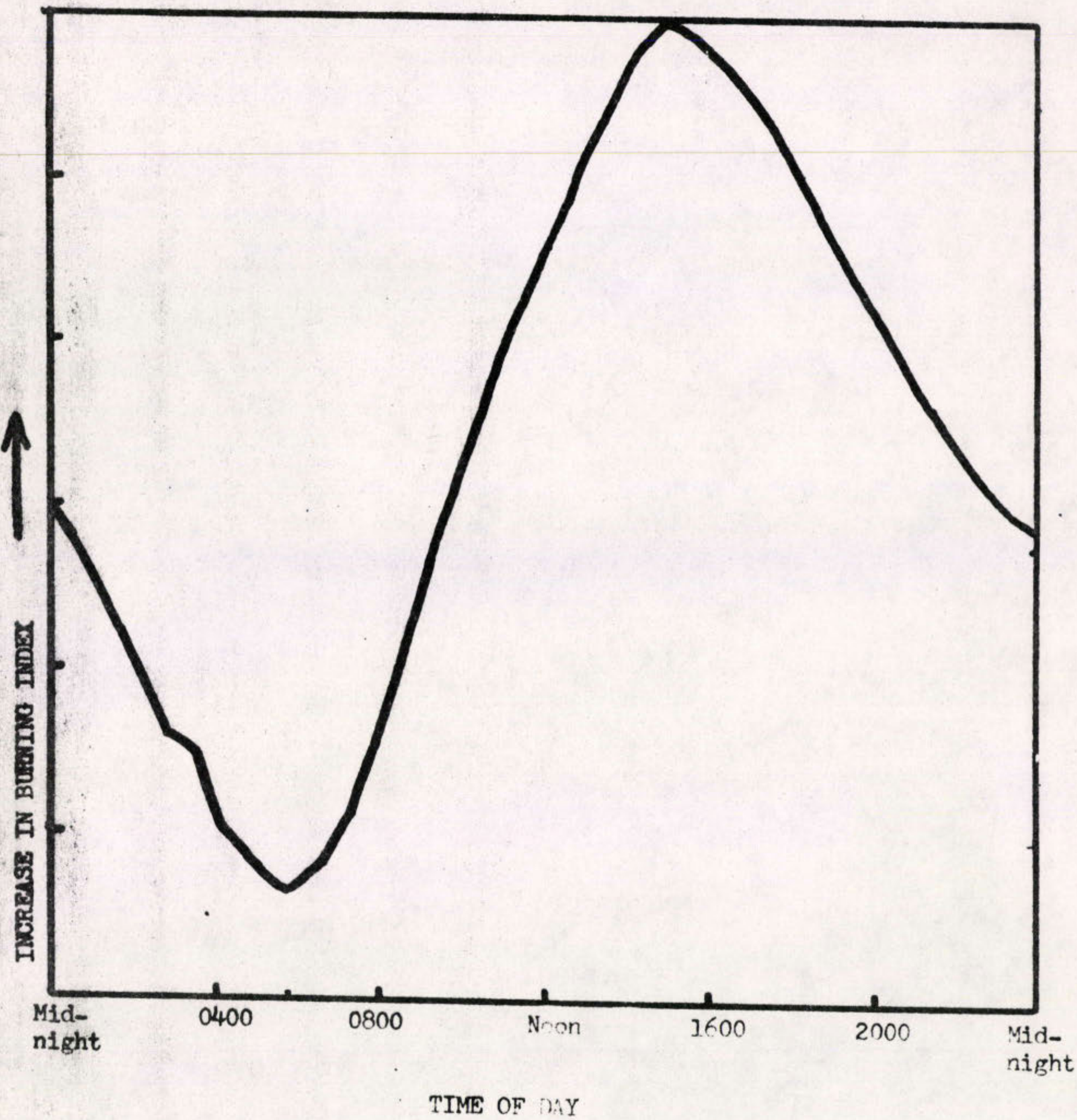
Logs under a forest canopy remain more moist through the season than those exposed to the sun and wind. These curves are 13 year averages for large logs of 6-, 12-, and 18- inch diameter.

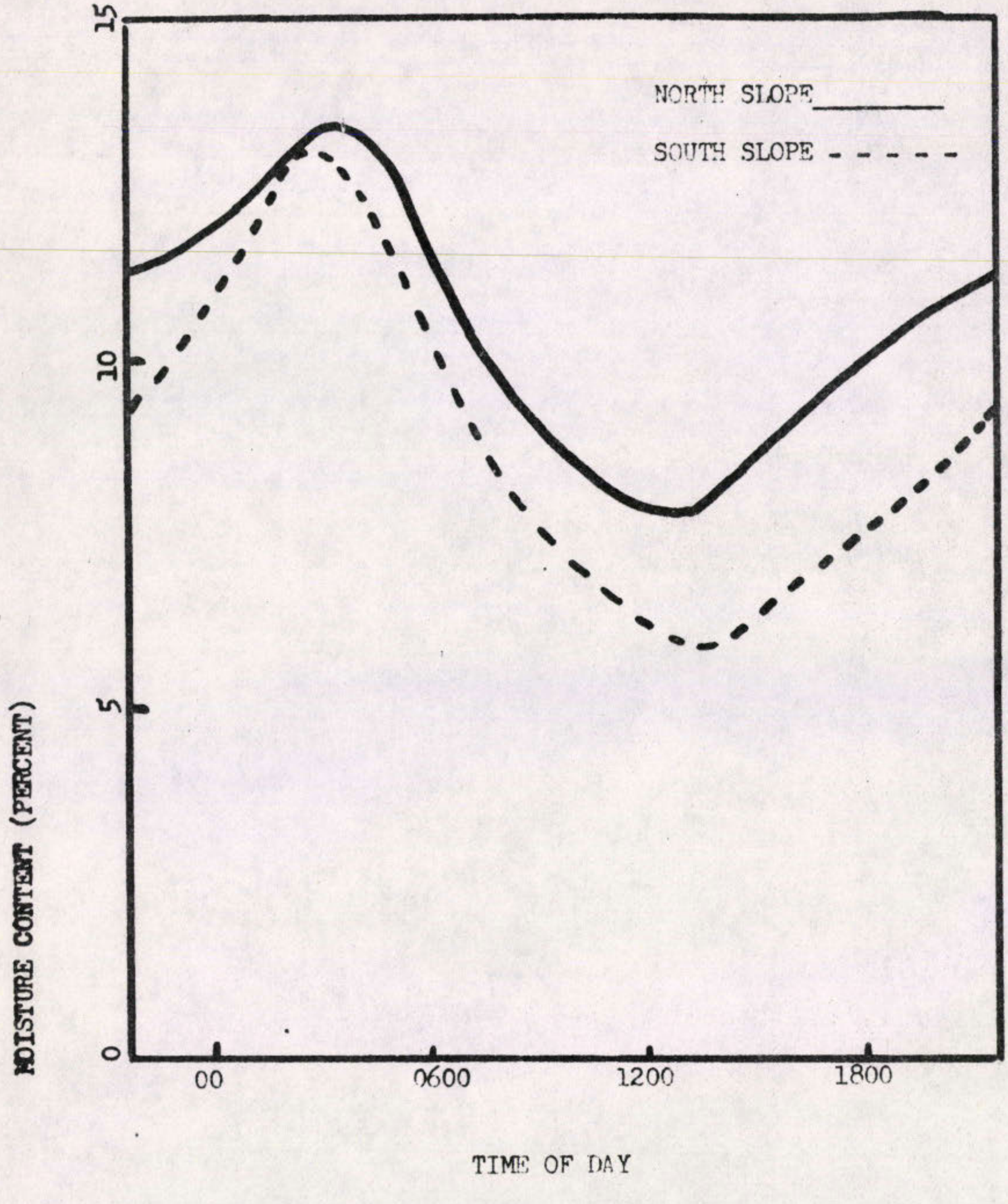
Variation in Fuel Moisture After Precipitation



Measurements of the moisture contents if different sizes of fuels before, during, and after precipitation show that larger fuels, such as logs, are slow to react to both wetting and drying.

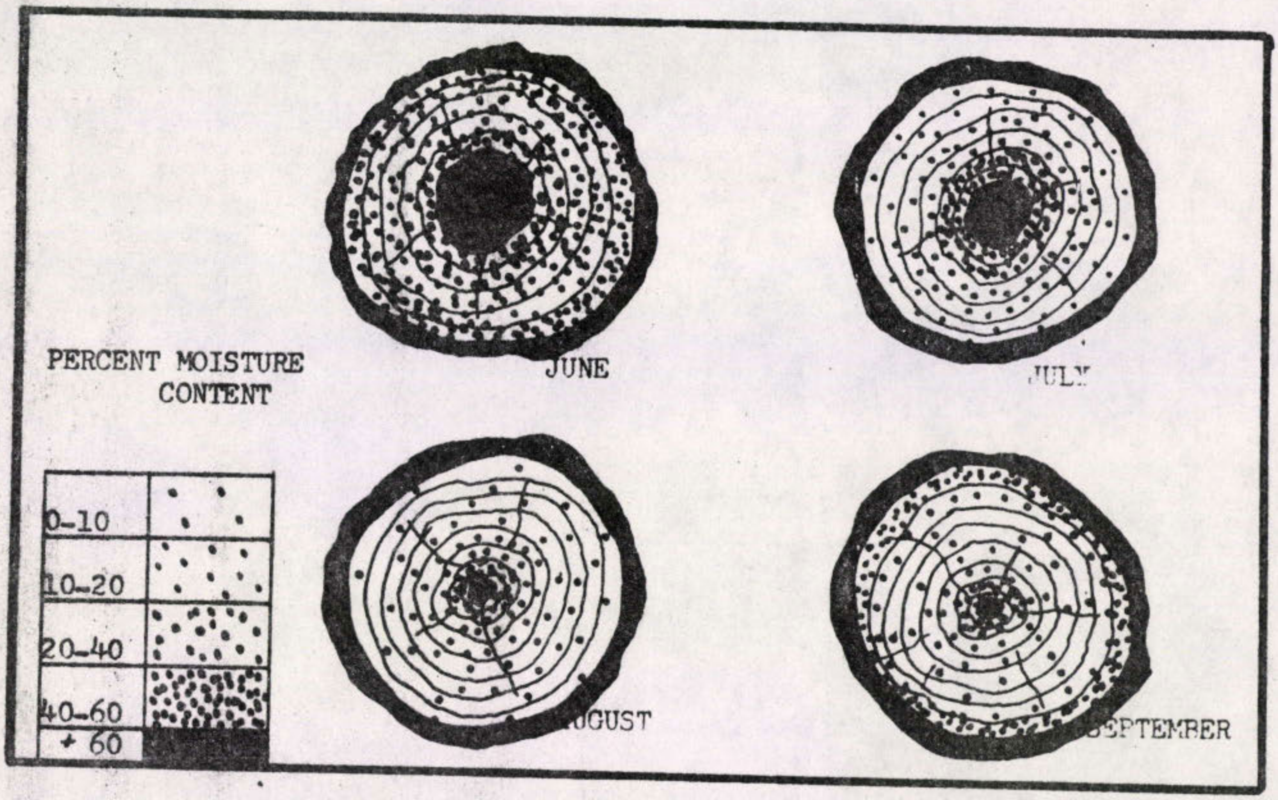
VARIATION IN BURNING INDEX ON A TYPICAL MID-SUMMER DAY





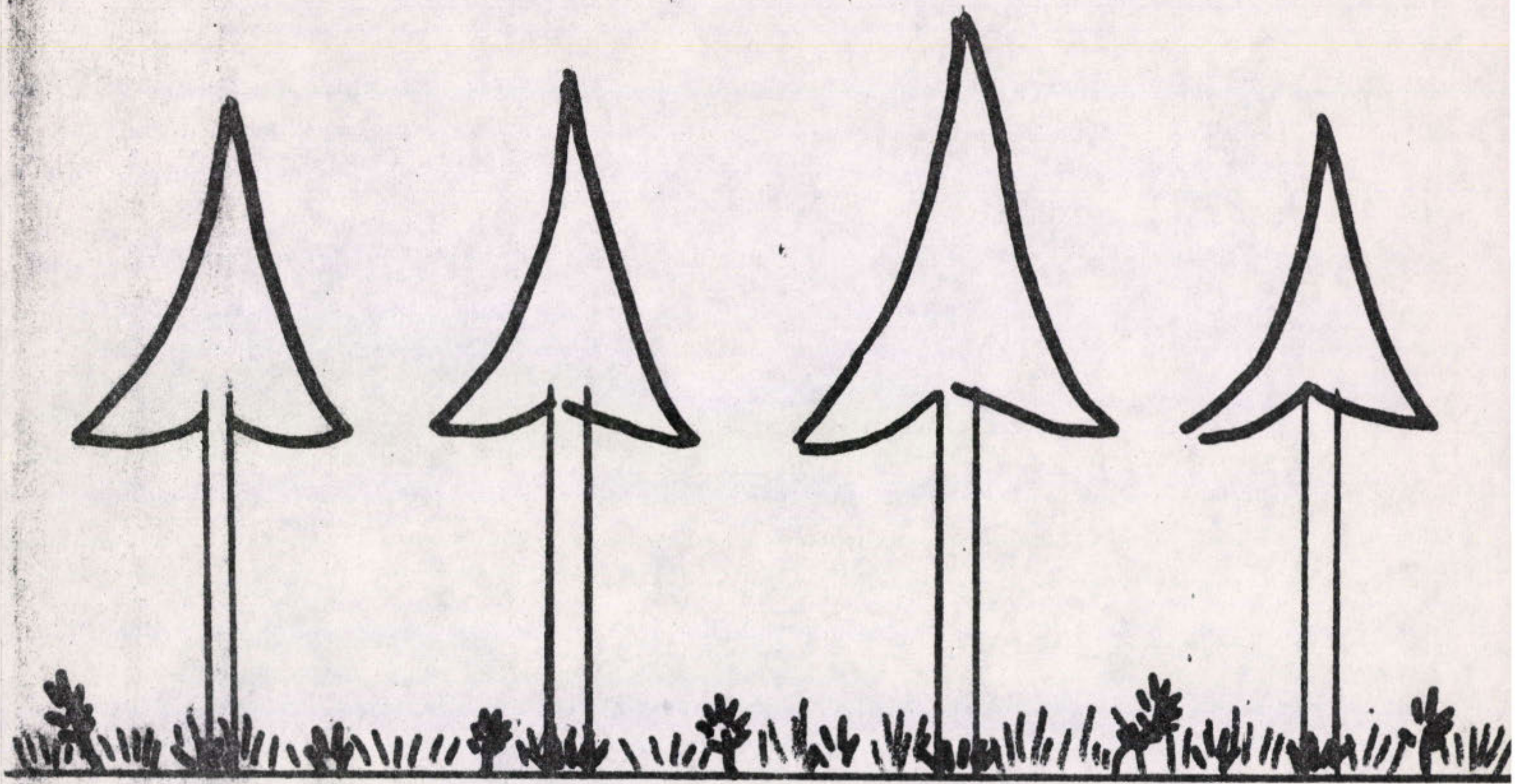
Variation in fuel moisture throughout the day in relation to aspect.

SEASONAL VARIATION IN FUEL MOISTURE OF LARGE LOGS

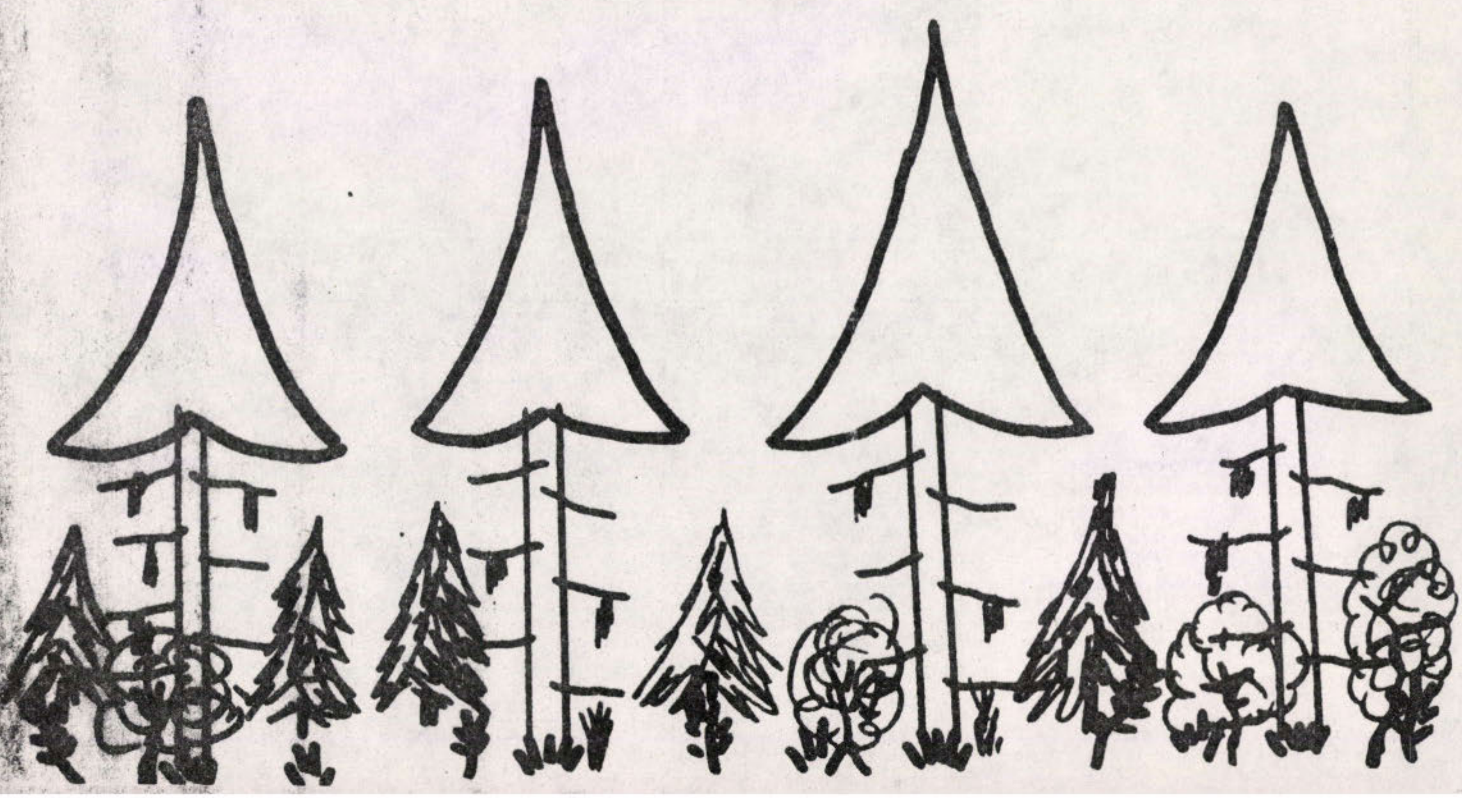


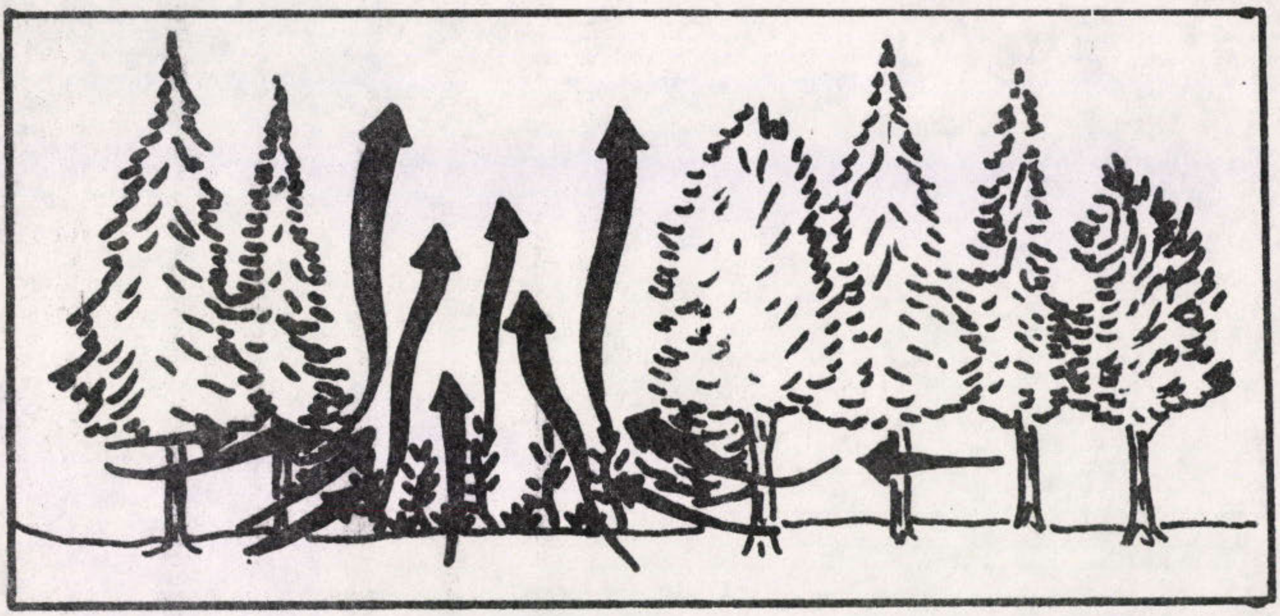
A large log, wet from winter percipitation, dries through the summer from the outside in. In the fall, as rains begin and temperatures and humidities moderate, the process is reversed and the log begins to take on moisture from the outside in.

NO VERTICAL CONTINUITY



MUCH VERTICAL CONTINUITY





Small openings in continuous canopies are sometimes the beginning place for crowning. These openings act as natural chimneys.

LIKELY MATERIALS FOR DISTANT SPOTTING

Bark

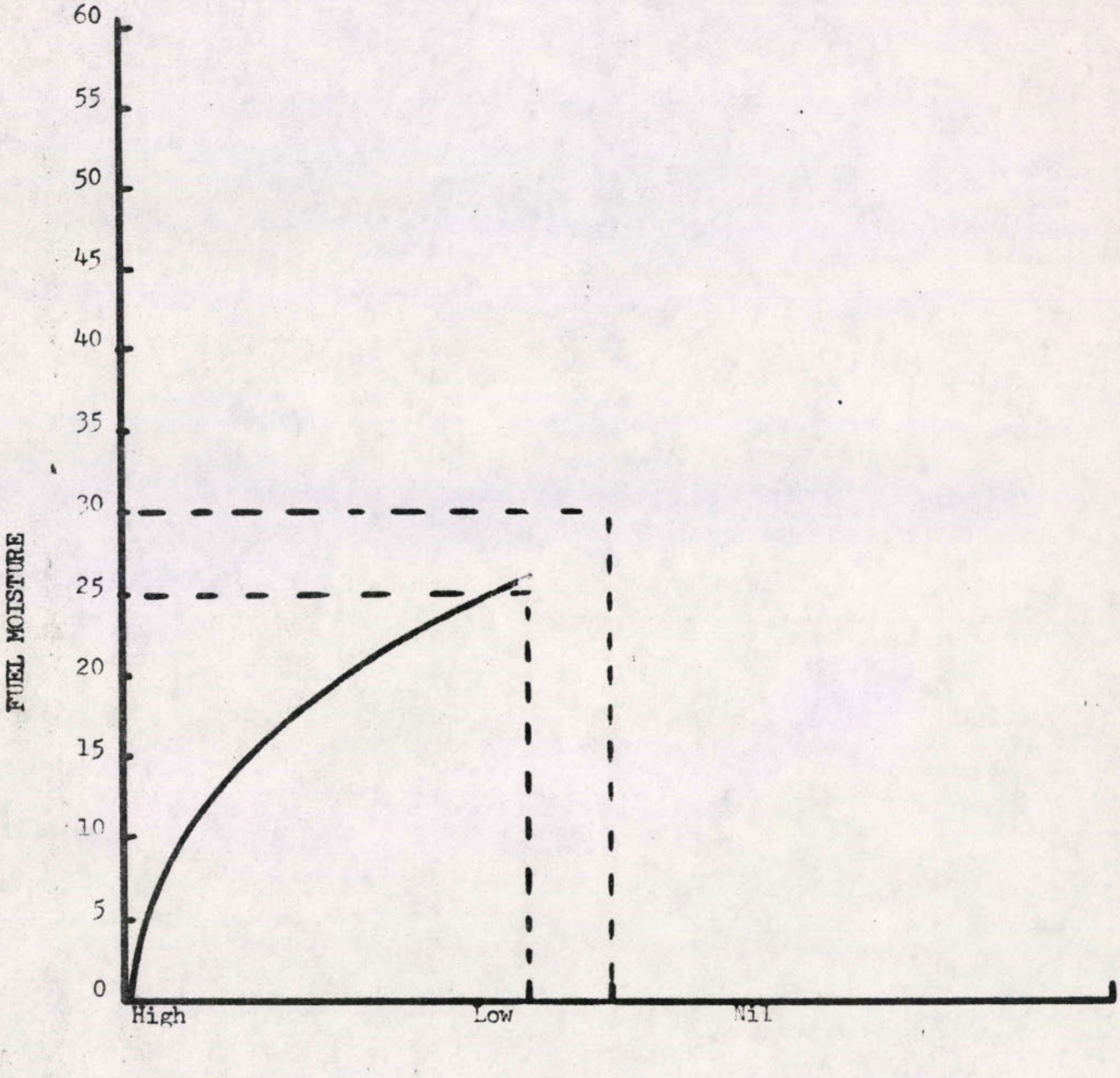
Low Density

Rotten Wood

Leaves

AIRFOIL

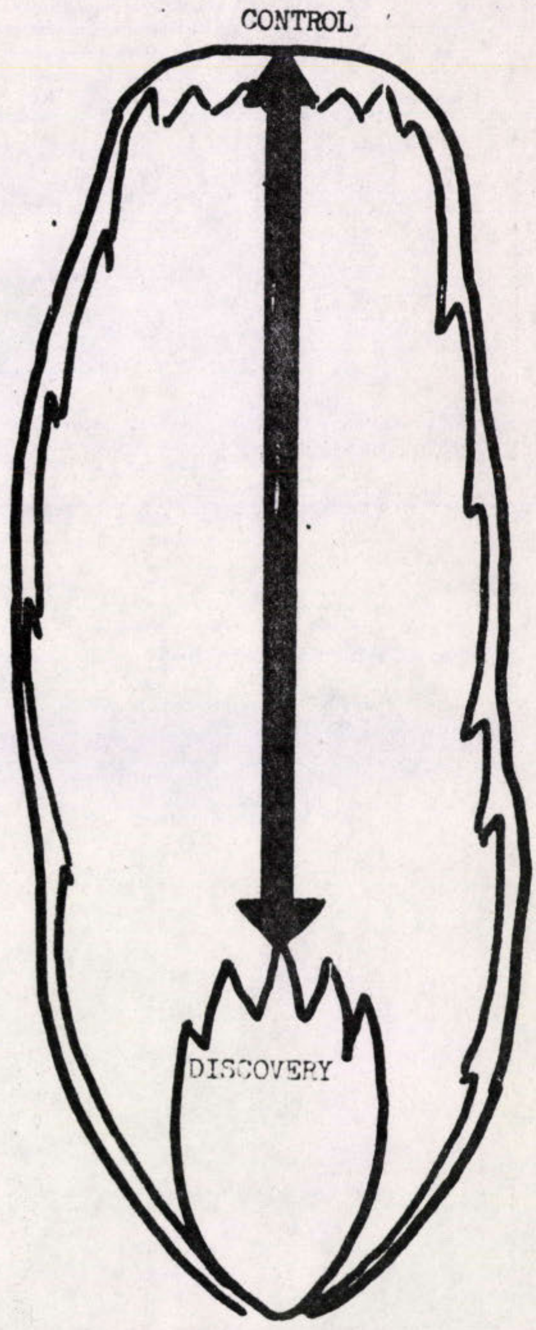
Tree bark



Ignition probability for most fire brands is essentially zero when fuel moisture is 25 to 30 percent.

Fl[illegible] Chart No. 13

LOW RATE OF SPREAD



HIGH RATE OF SPREAD

FUEL

1. SIZE
2. ARRANGEMENT
3. MOISTURE CONTENT
4. CONTINUITY
5. QUANTITY

FIRE

6. INTENSITY
7. PERSISTENCE

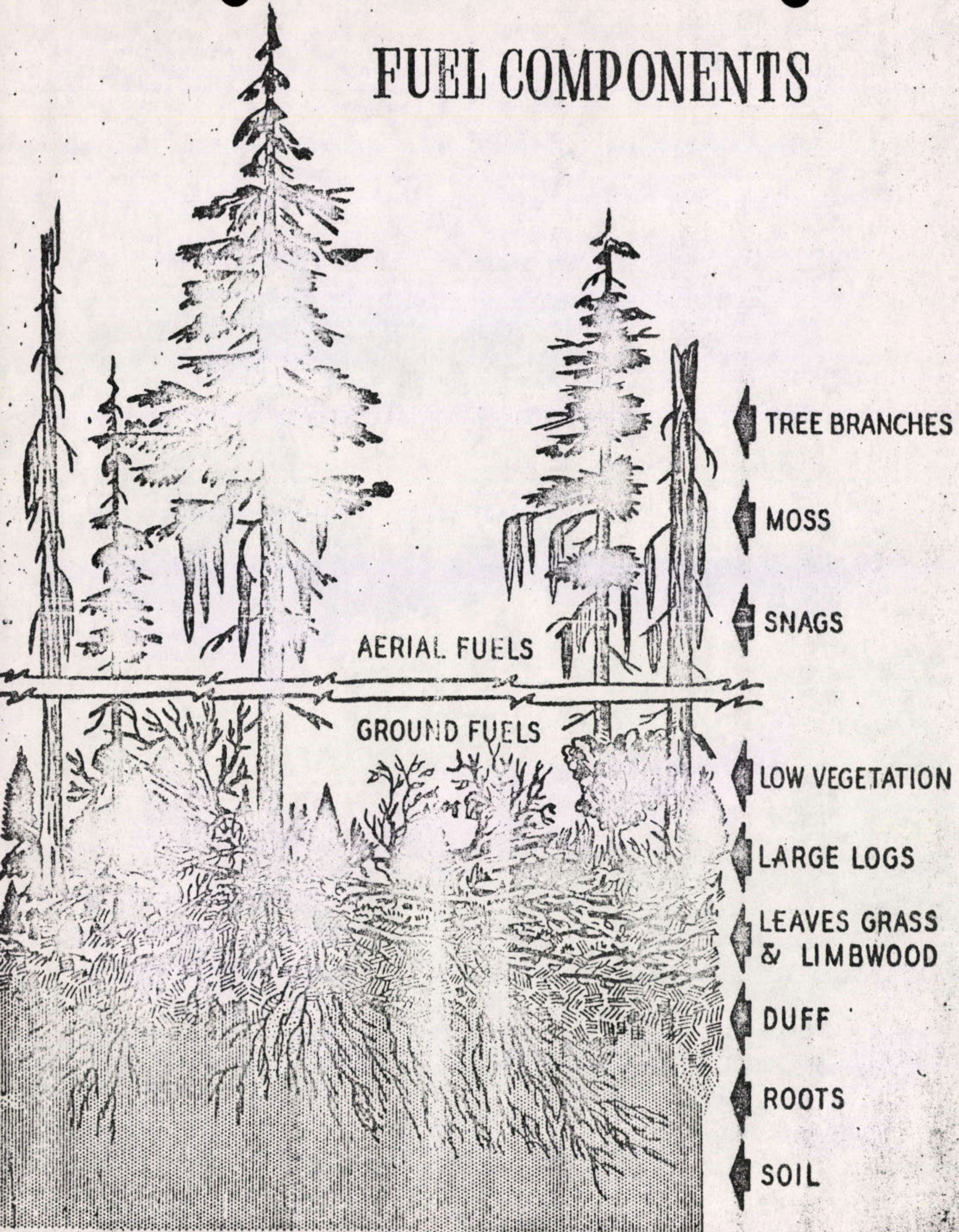
RELATED TO

A. EASE OF IGNITION
B. RATE-OF-SPREAD
C. RESISTENCE TO CONTROL

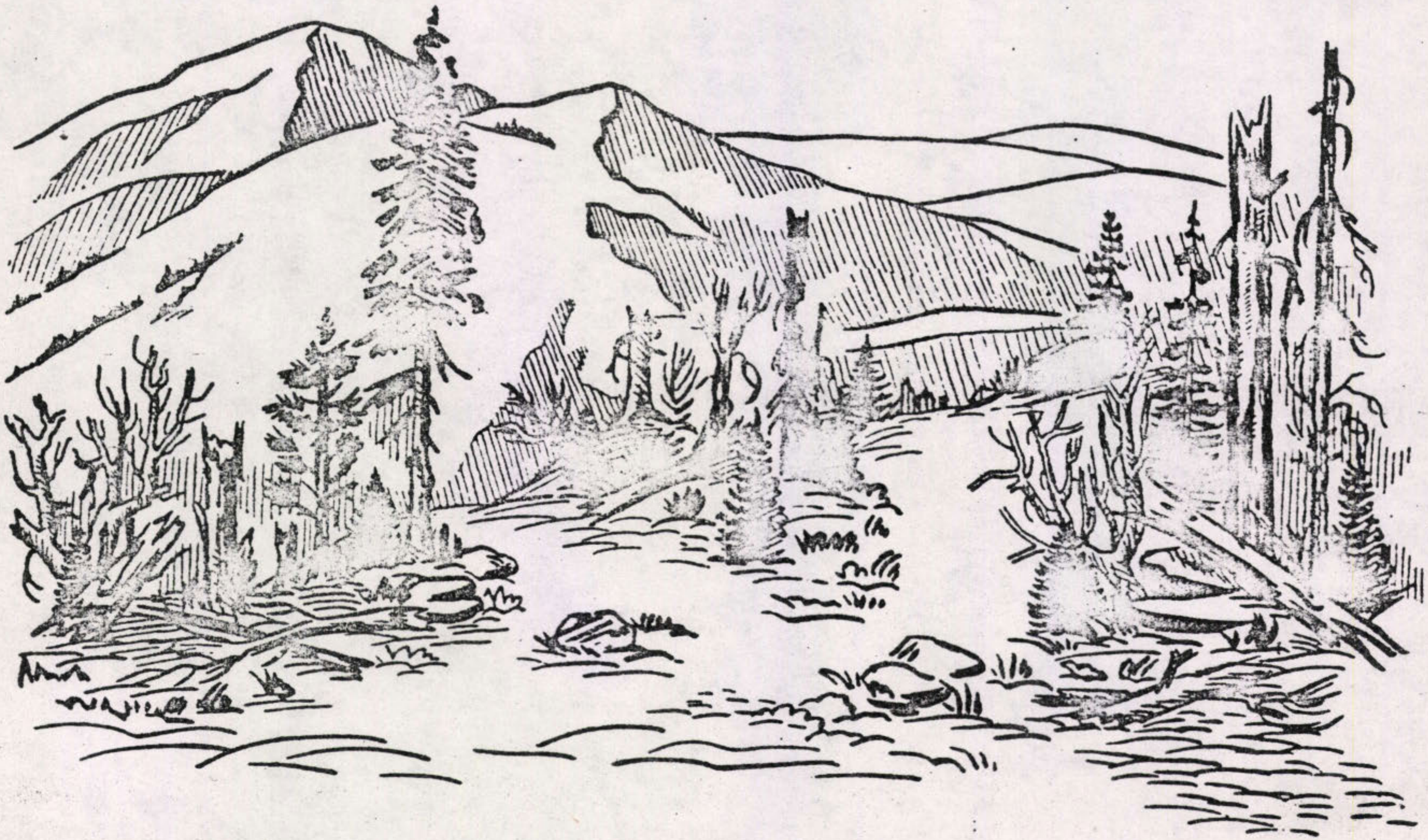
FIRE BEHAVIOR

A. SAFETY
B. UTILIZATION OF MANPOWER AND EQUIPMENT
C. PRE-ATTACK PLANNING
D. GET THE FIRE OUT

FUEL COMPONENTS

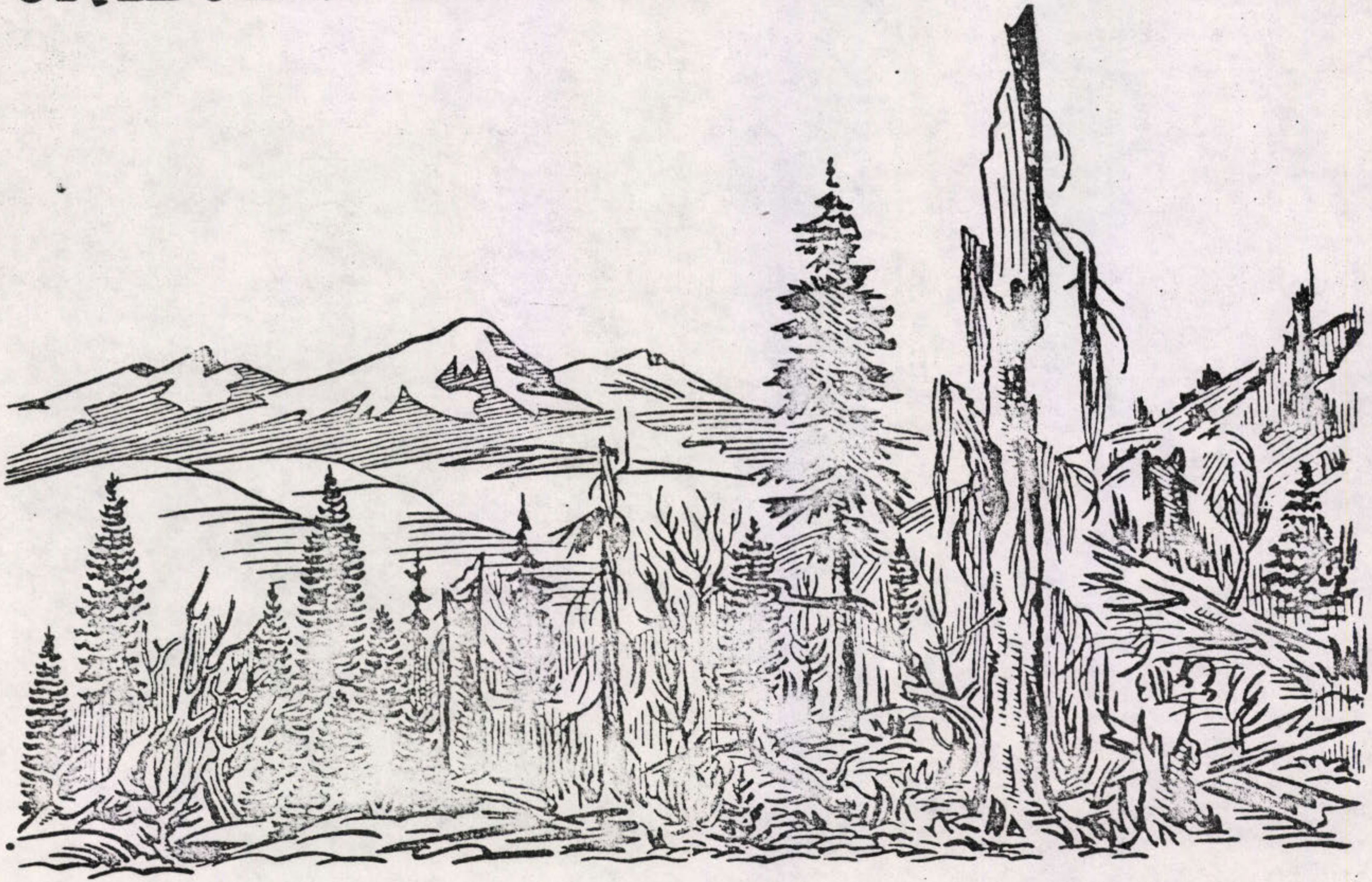


PATCHY FUELS



IV-A(2)

UNIFORM FUELS



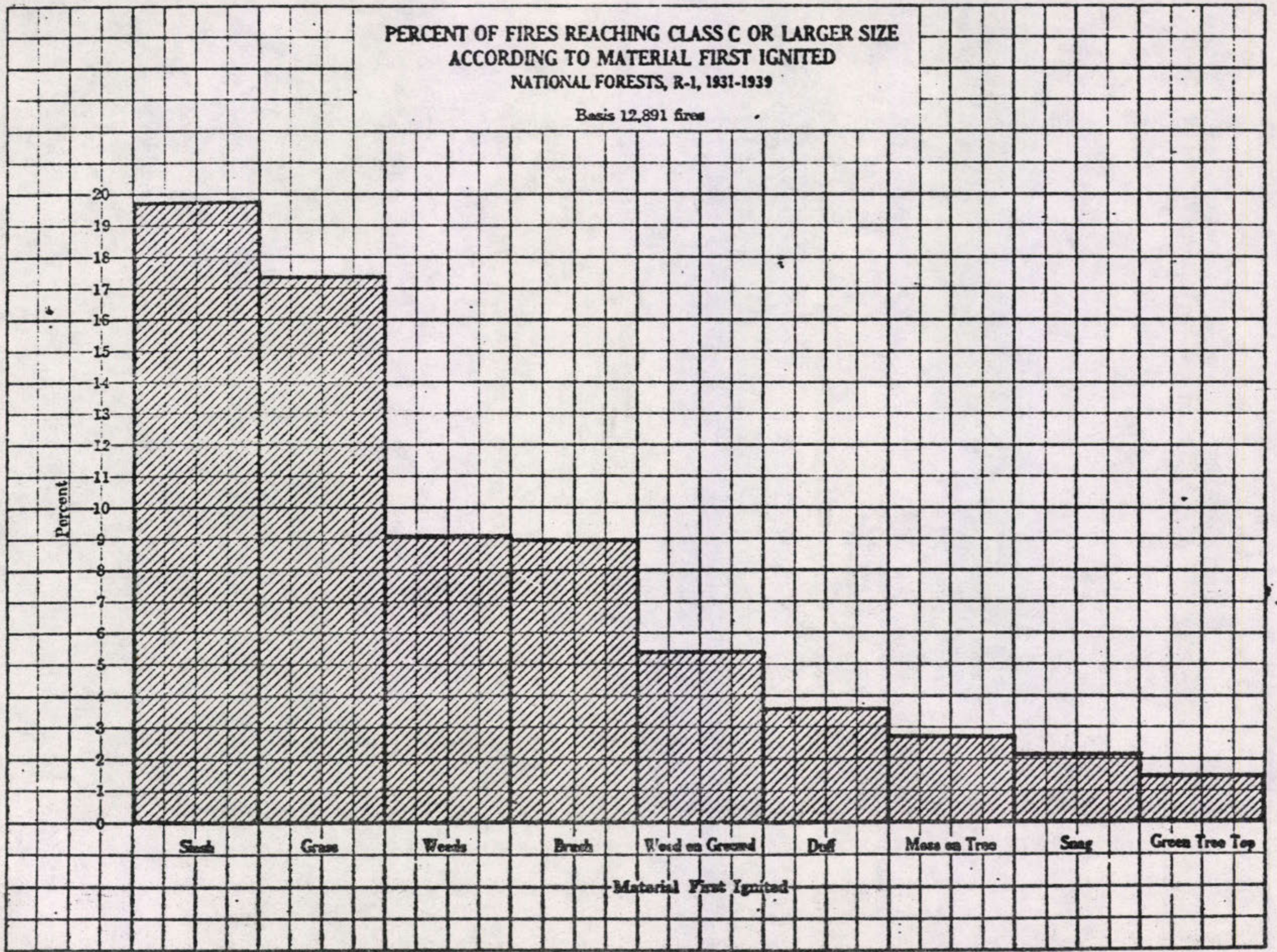

PERCENT OF FIRES REACHING CLASS C OR LARGER SIZE
ACCORDING TO MATERIAL FIRST IGNITED
NATIONAL FORESTS, R-1, 1931-1939
Basis 12,891 fires
Percent
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Slash
Grass
Weeds
Brush
Wood on Ground
Duff
Moss on Tree
Snag
Green Tree Top
Material First Ignited

Figure 41.

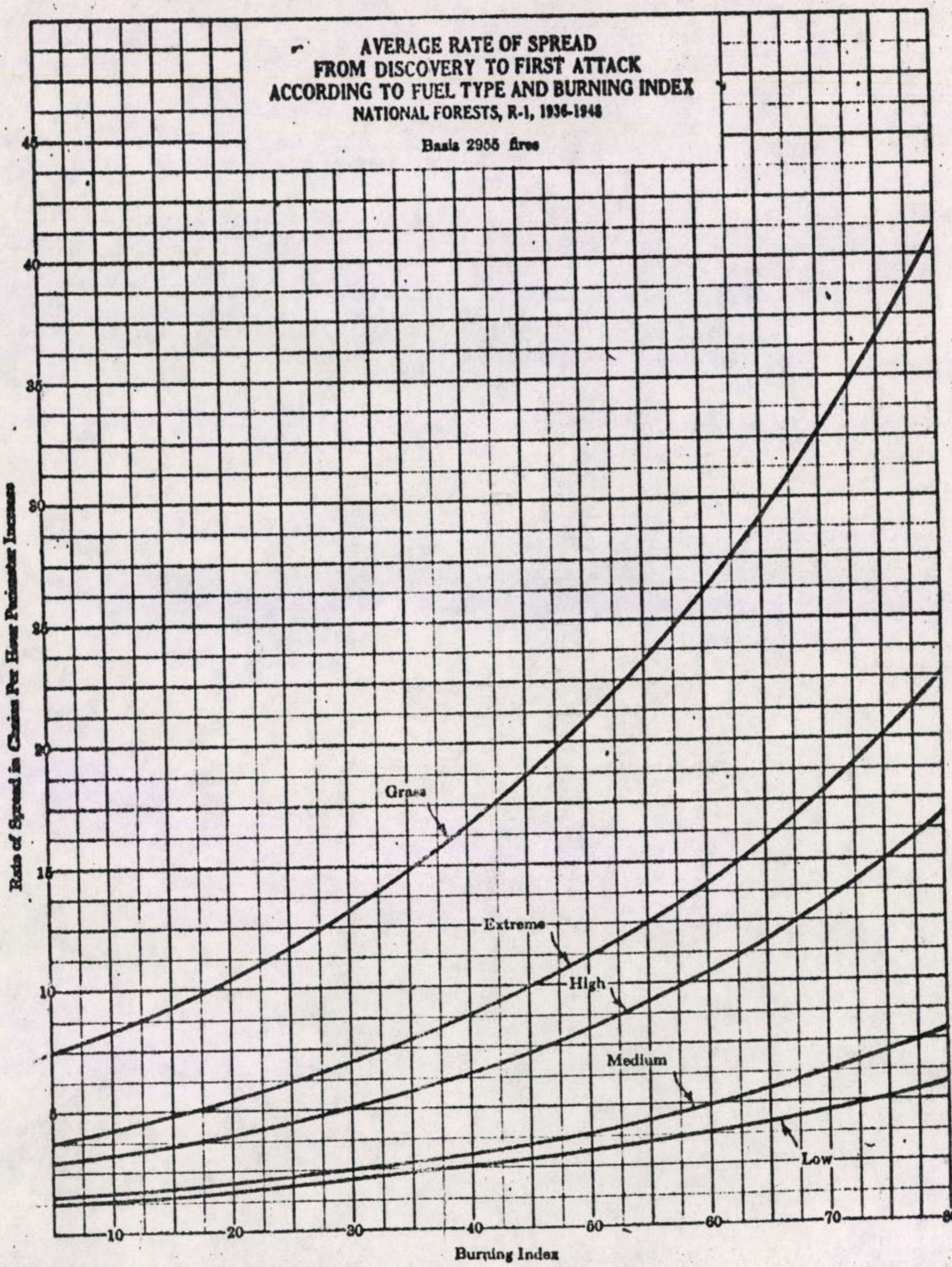
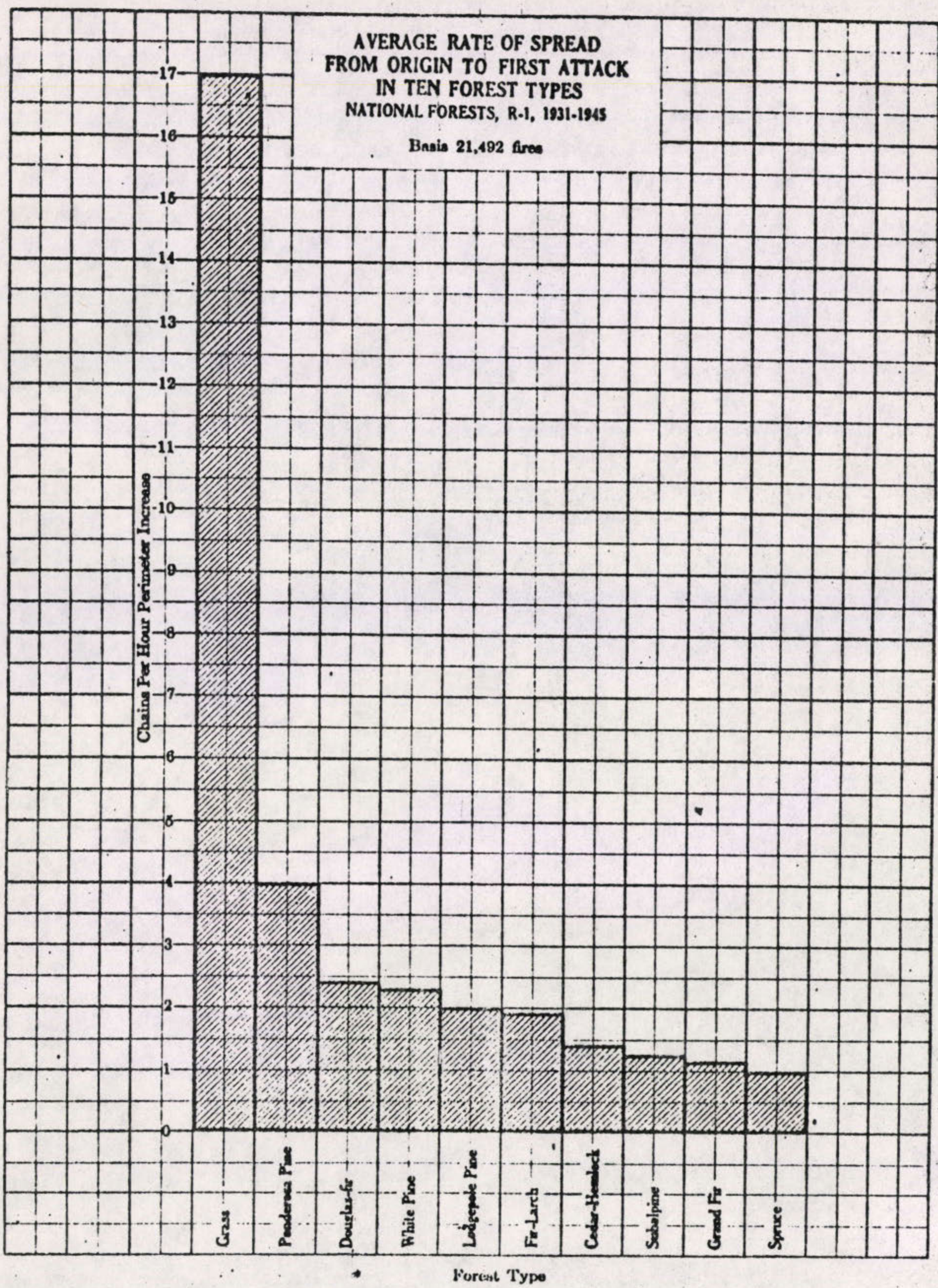
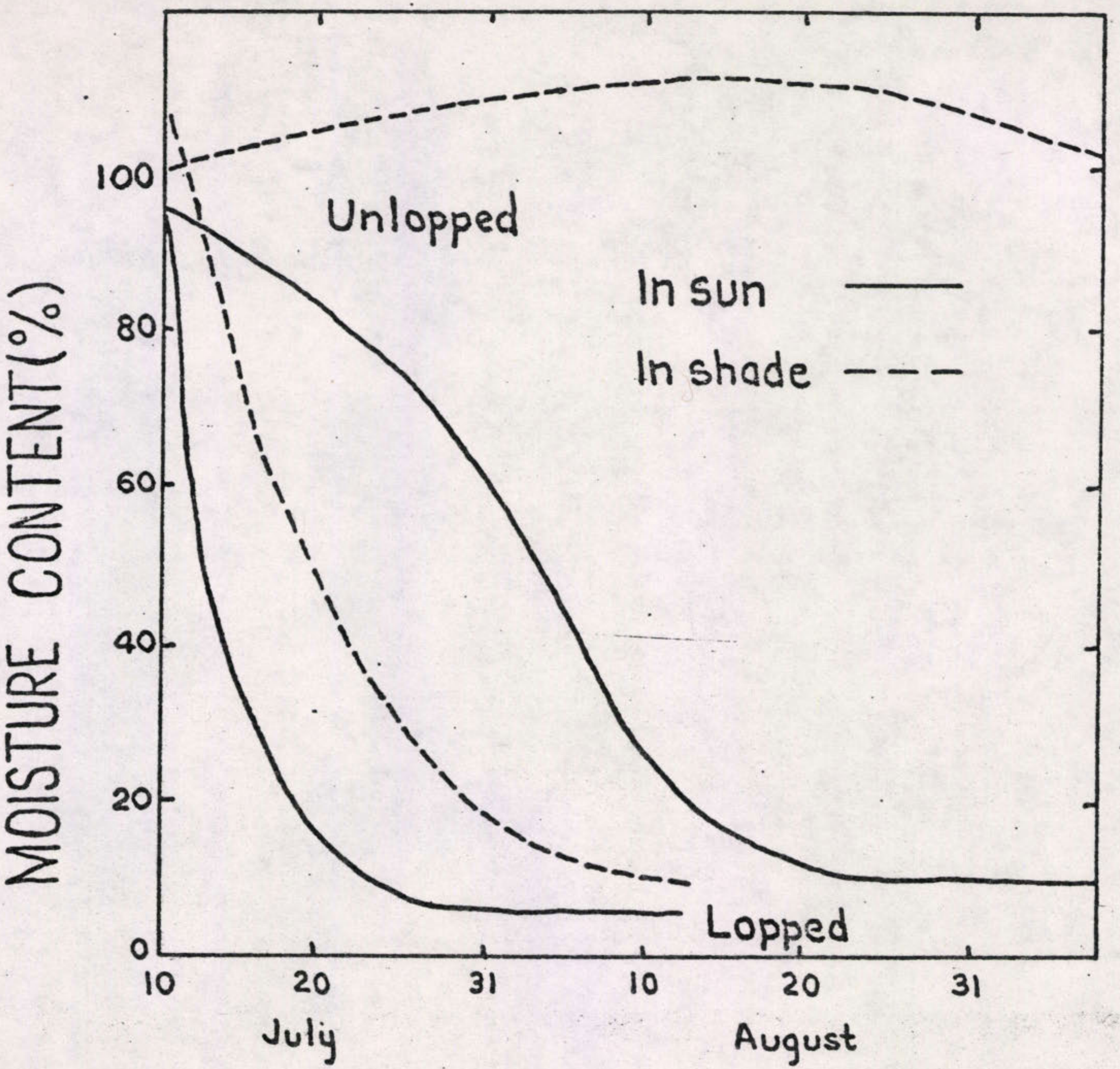

AVERAGE RATE OF SPREAD
FROM DISCOVERY TO FIRST ATTACK
ACCORDING TO FUEL TYPE AND BURNING INDEX
NATIONAL FORESTS, R-1, 1936-1948
Basis 2955 fires
Rate of Spread in Chains Per Hour Perimeter Increase
Burning Index
Grass
Extreme
High
Medium
Low
10
20
30
40
50
60
70
80
5
15
25
35
45

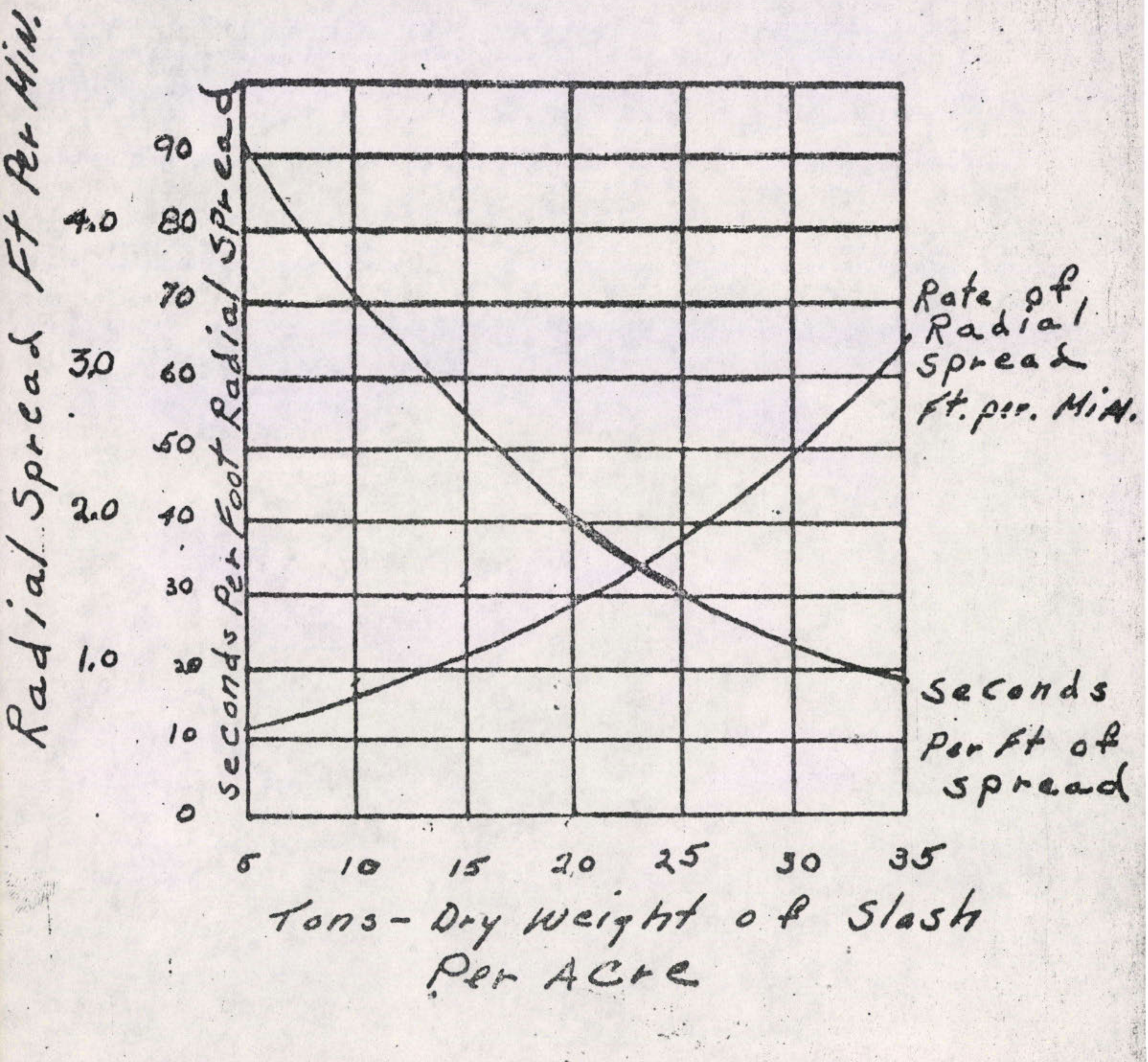
Figure 65.


AVERAGE RATE OF SPREAD
FROM ORIGIN TO FIRST ATTACK
IN TEN FOREST TYPES
NATIONAL FORESTS, R-1, 1931-1945
Basis 21,492 fires
Chains Per Hour Perimeter Increase
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Grass
Ponderosa Pine
Douglas-fir
White Pine
Lodgepole Pine
Fir-Larch
Cedar-Hemlock
Subalpine
Grand Fir
Spruce
Forest Type



MOISTURE IN FOLIAGE

Rate of Spread With Increasing Tons of fuel Per Acre in current year's slash of White Pine, Cedar and Douglas Fir



INSTRUCTOR'S LESSON PLAN

COURSE Intermediate Fire Behavior
INSTRUCTOR Lloyd D. Todd
LESSON Topography and Fire Behavior
FILE NO. 5100
START & STOP TIMES 0800 - 0900
NO. ASSISTANTS -----
METHOD OF INSTRUCTION Lecture with aids
NO. IN AUDIENCE 50 - 60
PLACE Fort Collins, Colorado
TRAINING AIDS View Graph and Easel
DATE March 16-18, 1971

OBJECTIVE Provide Trainees with the background for evaluating the effects of topography on fire behavior so that they may do a better job of sizing up a fire and planning strategy.

TIME	LESSON OUTLINE	AIDS & CUES
0800	I. <u>Introduction</u>: In the next hour we will cover the second leg of the fire triangle, "TOPOGRAPHY". Topography has an effect on the climate of small areas, the current weather, the physical motion of fires and the barriers that may effect fire spread. Let's take a look at page 15 in the R-2 Fire Line Notebook to see how Topography fits into the factors to consider in calculating probability.	

TIME	LESSON OUTLINE		AIDS & CUES
	22 FACTORS TO CONSIDER IN CALCULATING PROBABLITIES		
	1. Temperature		View Graph #1
	2. Humidity.		
	3. Wind.	to date and fore-cast.	
	4. Fuel Moisture		
	5. Topography.	slope in percent, approximate; general character; effect on wind movement; soil formation.	
	6. Exposure as it affects. . . .	temperature; humid-ity; fuel moisture; convection cur-rents.	
	7. Fuel Type	in which fire has burned; in which fire is burning; ahead of fire.	
	8. Barriers.	natural; artifical.	
	9. History of Fire	from origin to date; knowledge of how past fires be-haved in the same or similar areas.	

TIME	LESSON OUTLINE	AIDS & CUES

II. Development

A. Aspect (Exposure) — View Graph #2

Aspect describes the direction in which a slope faces.

Factors that illustrate typical variations caused by aspect on a summer day at noon with a clear sky:

Factors	South	West	North	East
Amount of Available Sunshine	100%	80%	40%	60%
Temperature Air-Fuel-Soil	High	Moderately High	Moderately Low	Moderate
Fuel Volume and Type	Light-sparse flashy	Mod. light Mod. flashy	Heavy-dense Slow burning	Mod. Heavy Mixed
Air Moisture and Fuel Moisture	Low	Moderately Low	Moderately High	Moderate

TIME	LESSON OUTLINE	AIDS & CUES

Effects of aspect on ignition rate (occurrence) and size of fire. (Based on a study of more than 21,000 fires.)

Aspect	Ignition Ratio	% Fires Class C or Larger
Northwest	1.0	3.6
North	1.1	2.7
Northeast	1.2	3.4
East	1.3	3.7
Southeast	1.3	5.0
South	1.7	6.8
Southwest	1.6	7.2
West	1.3	4.7

View Graph #3

TIME	LESSON OUTLINE	AIDS & CUES
	B. Elevation	
	Two broad factors - elevation above sea level in relation to surrounding country.	
	Elevation above sea level influence these factors:	Question Trainees
	General climate of area - snow melt dates - types and volume of fuels - stages of vegetation growth amount of precipitation - length of fire season - severity of daily and seasonal fire danger.	Replies on easel
	Average surface temperature correction = 4 degrees per 1,000 feet.	
	Average surface humidity correction = 2% per 1,000 feet.	
	Latitude is also a governing factor. Example: The North-south distance in State of California causes a climatic effect on vegetation comparable to about 4,000 feet difference in elevation. In	

TIME	LESSON OUTLINE	AIDS & CUES
	the north, Ponderosa Pine yield to fir and high elevation pines at about 5,000 feet. In southern California the Ponderosa Pine rarely grows below the 5,000 foot elevation.	
	<u>Elevation in Relation to Surrounding Country</u>	
	Mountain tops and valley bottoms in areas having continental climates have different burning conditions as follows:	
	Valley bottoms - days - heated air rises - 8 a.m. to 8 pm. most dangerous fire conditions.	View Graph #4
	Mountain tops - nights - heavier cold air drains into valley - higher night temperature - fire danger higher - fires may be more active than in valley.	

TIME	LESSON OUTLINE	AIDS & CUES

The Thermal Belt is generally situated in the middle of major mountain slopes and has four principal characteristics:

1. Zone of maximum temperature at night. — View Graph #5
2. Highest mean temperature.
3. Lowest average relative humidity during 24 hour period.
4. Lowest fuel moisture of any zone.

C. Combined Effects of Aspect, Elevation and Period of Day

Using spread index as a measurement of fire behavior, the following comparison can be made between slopes and valley bottoms:

Elevations	North Slopes	South Slopes
Lower Elevations	S.I. lower all periods than at valley bottom stations.	S.I. slightly higher all periods, except during evening transition SI is about same as valley bottom.

TIME	LESSON OUTLINE		AIDS & CUES
	Thermal Belt	S.I. lower during day. S.I. higher at night. Same as valley bottom during evening transition.	S.I. is higher at all times than at any other elevation.
	Upper Elevations	S.I. lower during day. S.I. higher at night. About same as valley bottom at morning transition.	S.I. lower during day and during evening transition. S.I. higher at night and during morning transition.

Some Exceptions

The foregoing "rules of thumb" concerning effects on the topographic factors of aspect and elevation have some notable exceptions:

TIME	LESSON OUTLINE	AIDS & CUES
	Pacific Ocean and the westerly winds creates a marine climate along the Pacific Coast Range which tends to wipe out the thermal belt of the continental climate and sets up a mechanism for downslope afternoon winds on east-facing slopes of the coastal range.	
	D. <u>Steepness of Slope</u>	
	Other conditions being equal, fires burn more rapidly up steep slopes. Slope has the same effect as wind on the forward rate of spread of a fire. Generally as the steepness of a slope increases, the rate of spread increases. Rule of thumb for increase: Fire burning uphill on moderate slope (0-40%) will double speed when going to a steep slope (40-70%) and double again going from steep to very steep slope (70-100%).	View Graph #6

TIME	LESSON OUTLINE	AIDS & CUES

Rate of Spread Ratios-1/

Slope in Percent	Rate of Forward Spread Factor	(no allowance for spotting or rolling material)
-40 to -70	1.0	
-20 to -39	1.5	
- 5 to -19	2.5	Chart on Easel
± 0 to ± 5	5.0	
+ 5 to +19	7.5	Use Example on Easel
+20 to +39	10.0	
+40 to +70	22.5	

Example: Fire burning downhill on a -5 to -19% slope (factor 2.5) at rate of 2 chains per hour starts burning upslope on a +5 to +19 (factor 7.5). What is the forward rate of spread uphill:

TIME	LESSON OUTLINE	AIDS & CUES

Answer: 6 chains per hour (7.5 + 2.5 = 3 times as fast). [1]Data derived from Individual Fire Reports for California Region, U.S. Forest Service.

Steep slopes exert several physical effects on a fire, such as:

1. Fire burning uphill will be wedge-shaped similar to shape of fire driven by strong wind.

2. Flames on flanks will be pulled inward by intense heat.

3. Spotting potential is increased by the convection currents carrying fire brands upslope.

4. Fire reaching top to slope, the flames will usually be bent backward toward rear of fire. This curling back is caused by natural rise of warm air up opposite slope as well as a tendency

TIME	LESSON OUTLINE	AIDS & CUES

of flames to be drawn back into the fire.

5. Rolling material will be a threat on steep slopes.

E. Position of Fire on Slope

Position of a fire on a slope is an important factor in the variability of fire behavior.

1. Fire starting at the bottom of a slope has an increased size potential due to the availability of continuous fuel.

2. An upslope spread is likely for fires that become well established at the base of a slope before the middle of the day.

TIME	LESSON OUTLINE	AIDS & CUES
	3. Fires positioned in the thermal belt may spread upslope during the middle of the day and afternoon, then tend to spread downslope after sundown continuing to burn intensely into the evening.	
	4. Fires on upper slopes will be strongly influenced by general prevailing winds with erratic behavior likely on the leeward side of the steep upper slopes because of air foil and eddy actions. Changes are likely after sunset and in the mid-morning period.	View Graph #7
	F. Shape of Country	
	In mountain areas the shape of the country is of great importance to the firefighter who must evaluate fire behavior. Some of the topographic features that influence fire behavior are:	

TIME	LESSON OUTLINE	AIDS & CUES
	Narrow Canyons	
	1. Wind directions will normally follow the direction of the canyon. But the local winds are likely to be deflected and wind eddies and strong upslope air movement may be expected at sharp bends in the canyon.	View Graph #8 View Graph #9
	2. Spotting from one slope to another is great, fires cross canyon readily.	
	3. Venturi effect on local up canyon thermal induced winds will be evident in narrow canyons.	
	Intersecting Drainages	
	1. Wind direction may be changed markedly at intersection.	
	2. Difficult to predict which canyon will dominate wind.	

TIME	LESSON OUTLINE	AIDS & CUES
	3. Gusty eddy currents are common at point of intersection.	Easel
	Wide Canyons	
	1. Prevailing wind direction will not be altered much be direction of canyon.	
	2. Cross-canyon spotting is not common, except in high winds.	
	3. Wide differences in general fire conditions between north and south aspects.	
	4. Diurnal wind changes will be evident.	
	Box Canyons - Chimneys	
	1. Fires starting near the base of a box canyon or chimney will react similar to a fire in a stove or fireplace.	

TIME	LESSON OUTLINE	AIDS & CUES
	2. Trapped gases near top of canyon due to poor ventilation can cause flash-over.	View Graph #10
	3. Air drawn in from canyon bottom will create very strong upslope drafts.	
	4. Similar conditions occur at the heads of narrow canyons or high mountain valleys.	
	Ridges	
	1. Fire burning along lateral ridges may change direction when it reaches a point where ridge drops off into canyon.	
	2. May be a whirling motion by fire around the point of a ridge caused by strong air flow around point.	

TIME	LESSON OUTLINE	AIDS & CUES
	3. Fire may slow down at crest of main slope as result of opposing air movement up other side of ridge.	
	4. Prominent ridges influence wind in the creation of roll eddy formations both horizontal and vertical, whirlwind formations, downslope wind patterns on leeward slopes.	
	<u>Saddles</u>	
	1. Increased and erratic air movement.	
	2. Roll eddy formations, both horizontal and vertical.	
	<u>Basins and Benches</u>	
	1. Whirlwind possibilities with long distance spotting.	
	2. Cold air sinks, local thermal belts.	

TIME	LESSON OUTLINE	AIDS & CUES

G. Barriers - Natural and Man-made

Natural - Rock slides, barren areas, lakes, rivers, wet meadows.

Man-made - Freeways, roads, firebreaks, fuelbreaks, powerline clearings*, reservoirs, subdivisions.

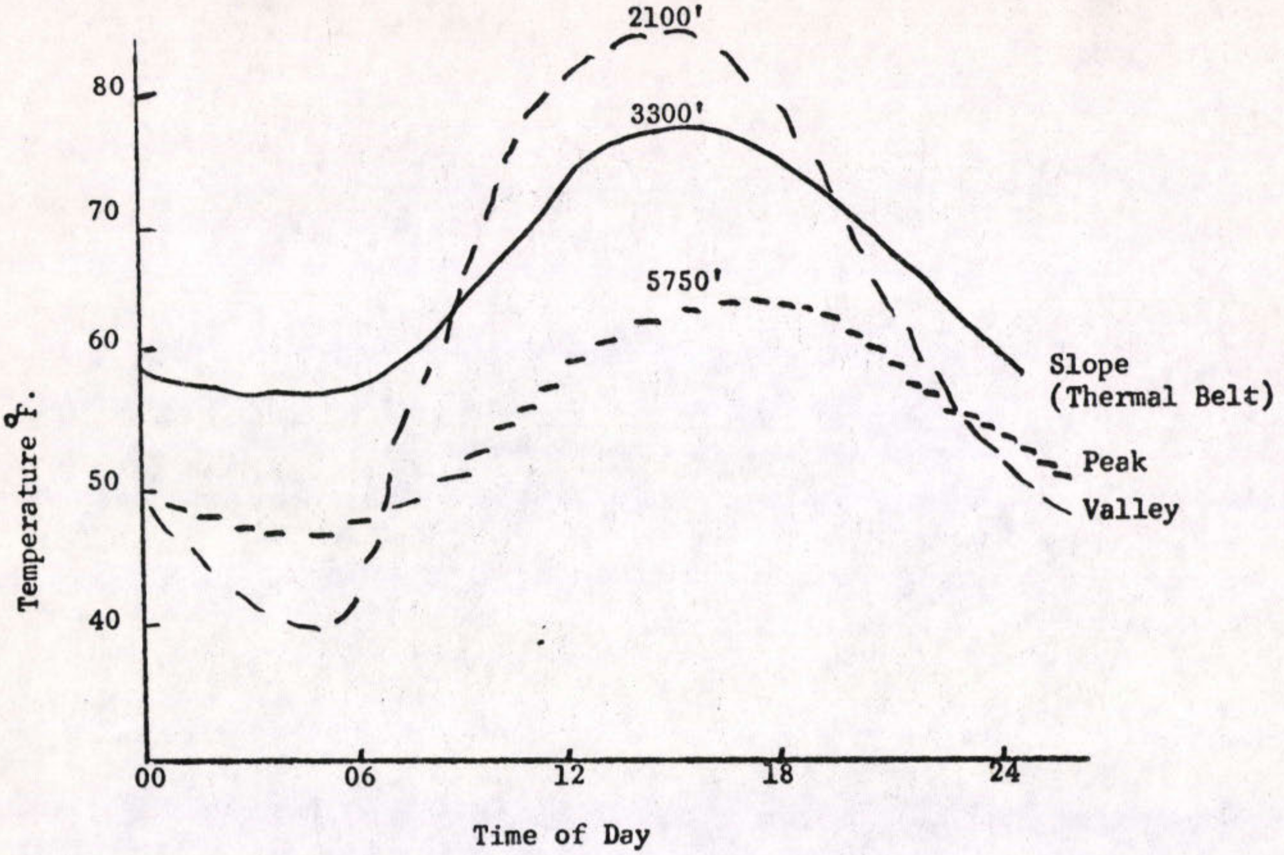
Barriers affect spread of fire directly through absence of fuels. Indirectly through modification of relative humidity, local winds and other fire climate conditions.

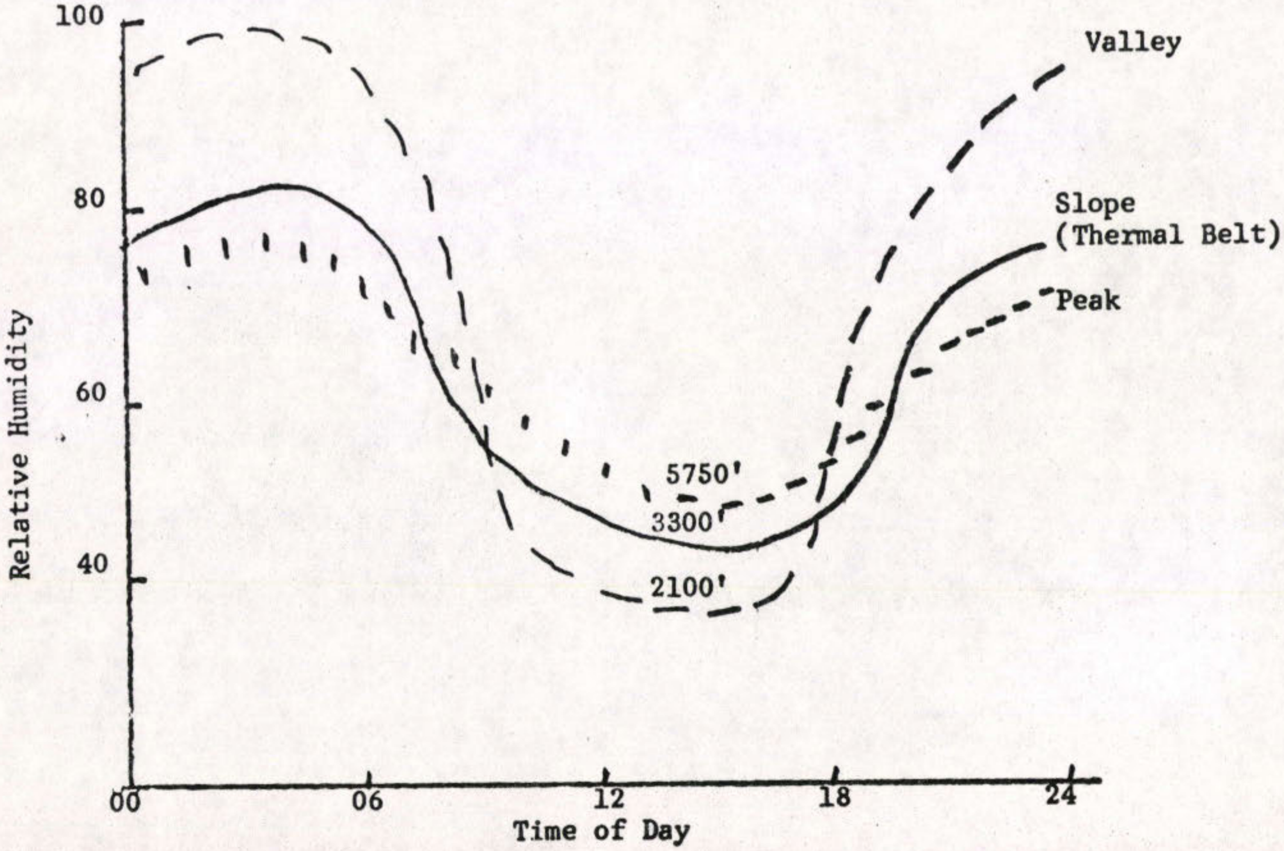
*Safety must be considered with possibility of powerline arcing to ground.

TIME	LESSON OUTLINE	AIDS & CUES
	III. Summary	
	In this session we have talked about:	Easel listing A-G
	A. Aspect	
	B. Elevation	
	C. Combined Effects	
	D. Steepness	
	E. Position on Slope	
	F. Shape of Country	
	G. Barriers	
	The combination of these make up only one part of the total picture that you must look at in order to properly appraise a fire situation. Miss one and you could miss the boat.	

TIME	LESSON OUTLINE	AIDS & CUES
	To do an adequate job of sizing up a fire and planning strategy you must look at the entire picture.	

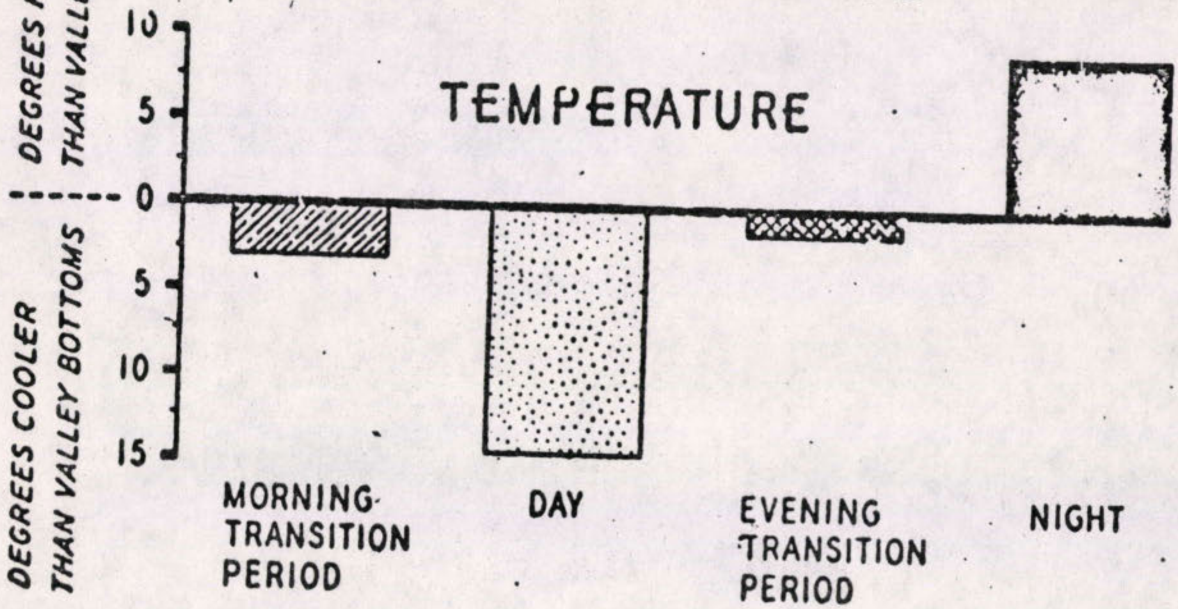
DIURNAL TEMPERATURE AND RELATIVE HUMIDITY CURVES AT DIFFERENT HEIGHTS #4

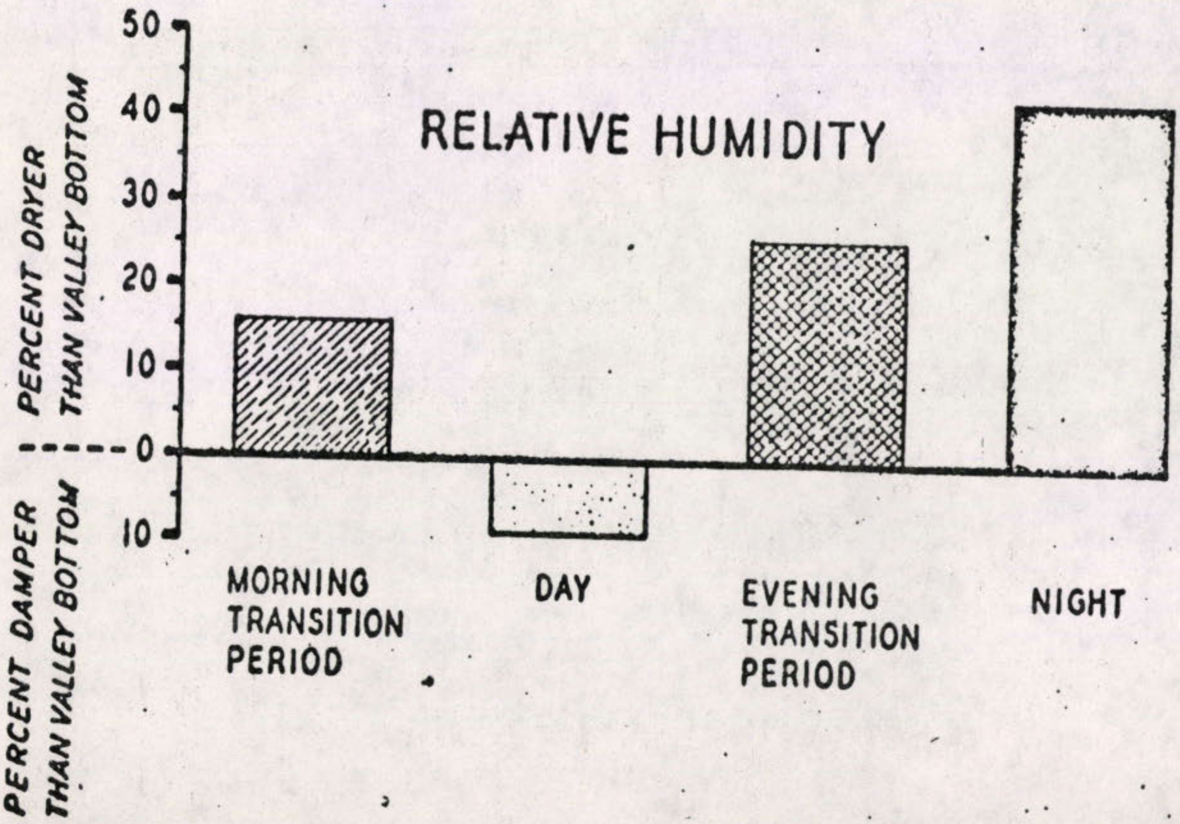




#4 IV-B (3)

HOW MOUNTAIN TOPS DIFFER FROM VALLEY BOTTOMS DURING MONTHS of JULY and AUGUST





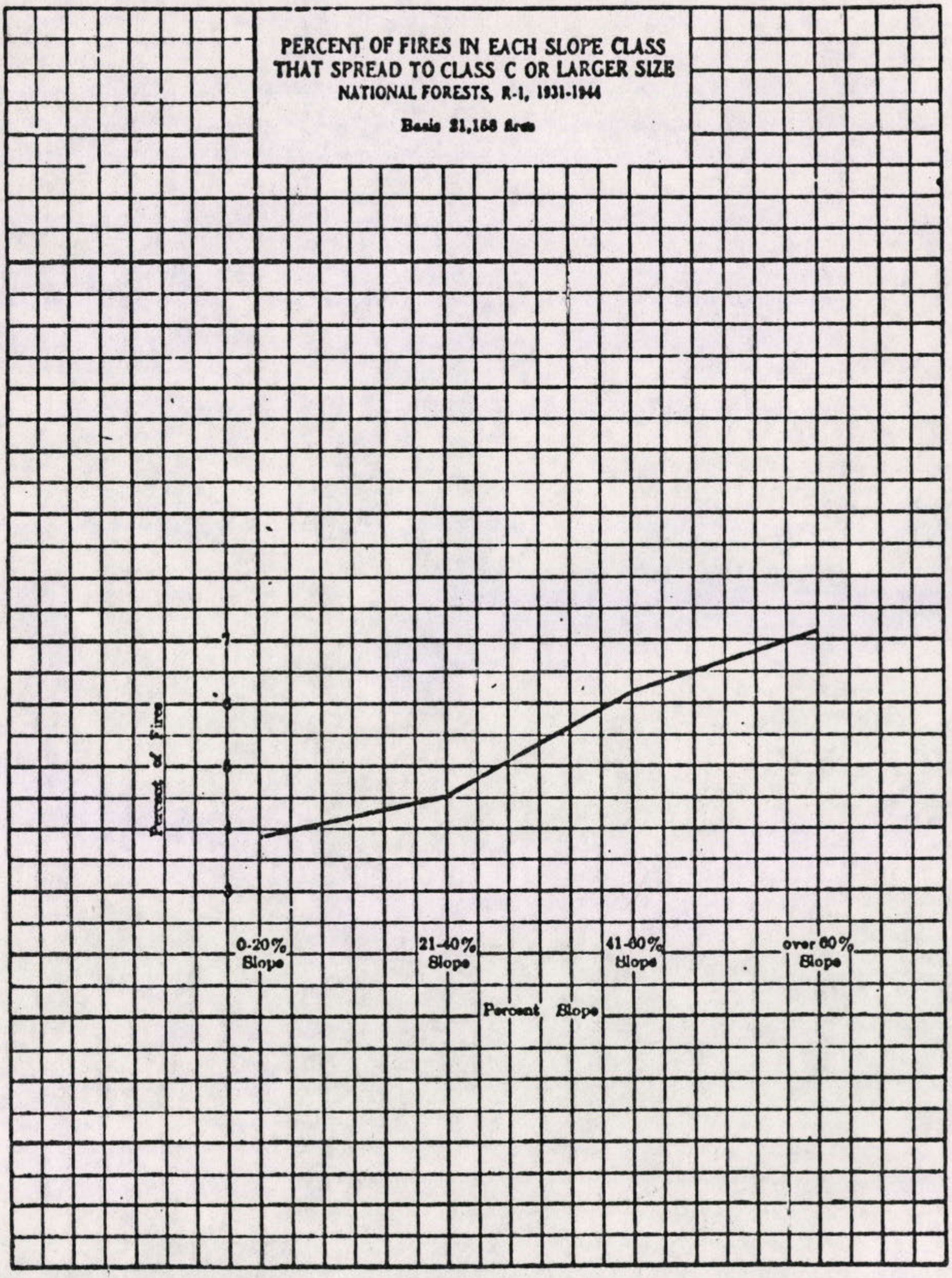
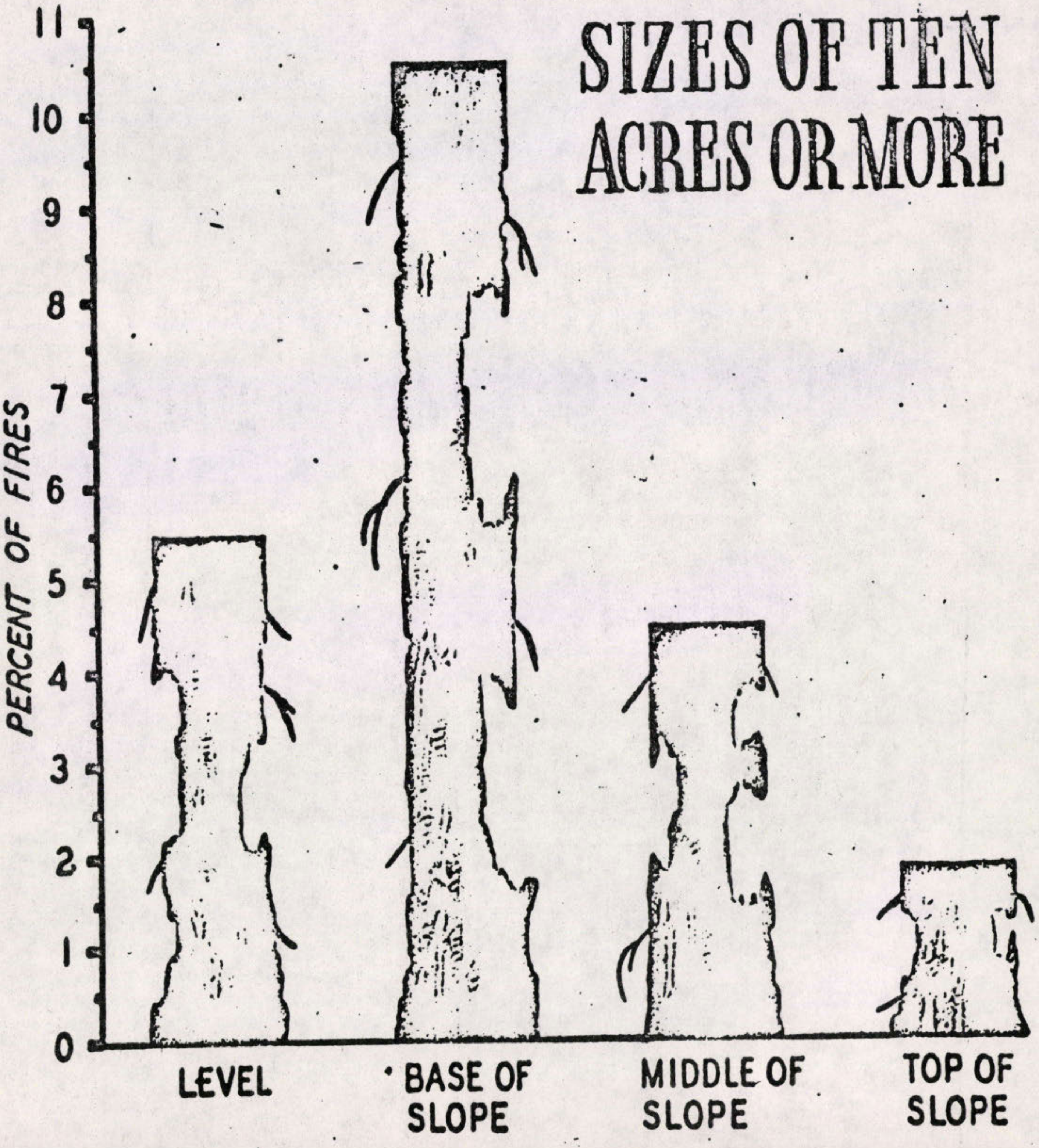

PERCENT OF FIRES IN EACH SLOPE CLASS
THAT SPREAD TO CLASS C OR LARGER SIZE
NATIONAL FORESTS, R-1, 1931-1944
Basis 21,158 fires
Percent of Fires
0-20% Slope
21-40% Slope
41-60% Slope
over 60% Slope
Percent Slope

Figure 31.

#7 IV-B(6

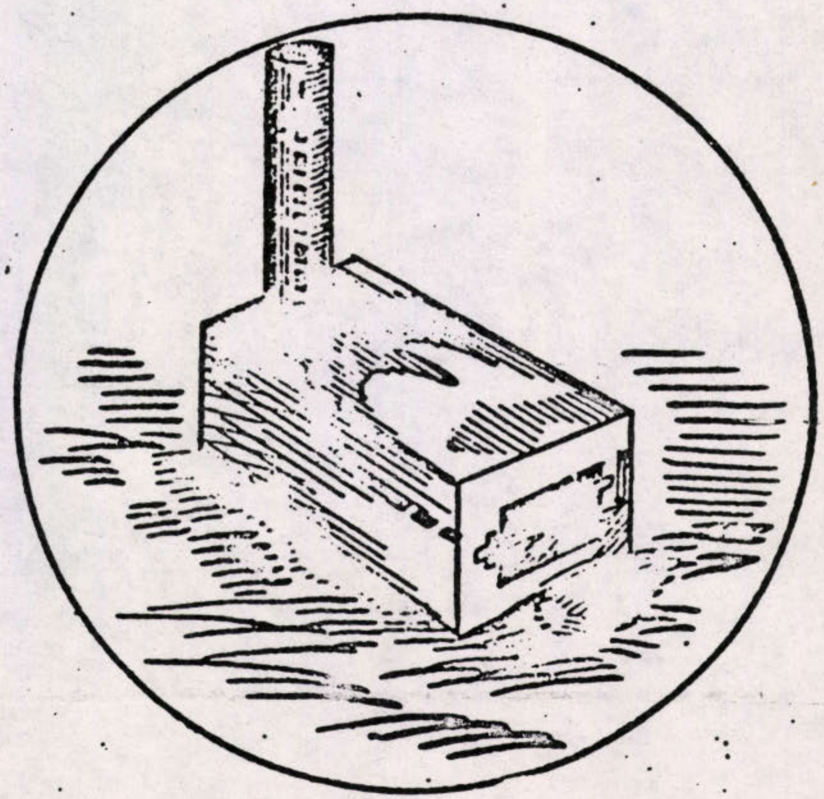
PERCENT OF FIRES IN EACH SLOPE POSITION REACHING SIZES OF TEN ACRES OR MORE



CANYONS FORM PATHS FOR THE FLOW OF AIR

FIRES EASILY CROSS NARROW CANYONS

FIRES IN A BOX CANYON HAVE AN UPWARD DRAFT LIKE A FIRE IN A STOVE



MASTER LESSON PLAN

SUBJECT: Fire Behavior

LESSON: WEATHER AND FIRE BEHAVIOR - IV-3

TYPE OF LESSON: Illustrated Lecture

TIME: One 50-minute period

PLACE: Classroom

AIDS NEEDED: Vu Graph (if available)
~~Opaque Projector~~
Slide Projector
Easel and Paper

OBJECTIVE: To explain specific effects of various weather factors on fire behavior

REFERENCES:

(1) Barrows, J. S. Fire behavior in northern Rocky Mountain forests. Station Paper 29, NRM Forest and Range Exp. Sta., Chapter III - Weather, pp. 26-45. 1951.

(2) Beers, Francis D. Some air mass characteristics conducive to development of thunderstorm downdraft winds in western United States. Paper presented at Western Fire-Weather Service Conf., Portland, Ore. 14 pp., mimeo. 1956.

(3) Byram, George M. Atmospheric conditions related to blow-up fires. Station Paper 35, SE Exp. Sta. 1954.

(4) Graham, Howard E. Fire whirlwinds. Paper presented at Western Fire-Weather Service Conf., Portland, Ore. 10 pp., mimeo. 1956.

(5) Krumm, W. R. Meteorological conditions which encourage explosive fire spread. Paper presented at Western Fire-Weather Service Conf., Portland, Ore. 19 pp., ditto. 1955.

(6) Krumm, W. R. Aspects of severe subsidence over Medicine Bow fires during July 1955. Paper presented at Western Fire-Weather Service Conf., Portland, Ore. 9 pp., plus weather charts, mimeo. 1956.

INTRODUCTION

When one thinks of the effect of weather on fire behavior, he probably has in mind such factors as relative humidity, temperature, surface wind, moisture content of fine fuels, and perhaps the precipitation pattern of the past few days.

During recent years close analysis of large fire behavior has revealed other important factors -- mostly atmospheric -- such as wind pattern aloft, atmospheric stability, and cloud types. Methods of measuring cumulative surface drying have resulted in evaluating the build-up of the fire season towards peak severity.

It is impossible to completely isolate each weather factor for discussion, as each one affects the others.

Evaluation of weather as it affects fire behavior becomes a complex problem. Some factors can be measured and some can be estimated, but many factors dealing with the upper atmosphere can only be determined by the fire-weather forecaster.

Most weather factors are interrelated with all the other factors. One cannot memorize how each combination of weather, fuels, and topography is going to affect the behavior of any single fire. A good understanding of the basic principles is essential; then one can size up a situation, apply his knowledge of the principles involved, and then take the proper steps to outmaneuver Old Mother Nature.

DEVELOPMENT

I. CUMULATIVE WEATHER EFFECTS ON FIRE BEHAVIOR

A forest fire will generally burn more intensely near the end of the fire season than it will at the beginning. This will happen even when the measured weather factors are the same -- humidity, wind, fuel moisture, temperature.

Vu Chart 10-4, Large Logs, easy and tough years) (Drying after 3 intensities of precip.)

The length of time since snow left the fuels or since the winter rain ceased determines the amount of drying weather to which the fuels are subjected.

The summer precipitation pattern has a bearing on the readiness of fuels to burn. A few heavy thunderstorms will not keep fuels as moist as will many frequent but light rains. Lots of spring rain, of course, delays the time when fuel moistures do become critical.

Vu Chart IV-3a

The amount of new vegetation is dependent partly on the amount and frequency of spring rains. Luxurious growth of fine fuels is an added deterrent to fire spread and intensity early in the season but when cured, this added fuel volume greatly intensified the behavior of a fire.

The ratio between green and dead material is important to observe. An apparently greenbrush stand can contain a tremendous amount of dead stems, twigs, and ground fuels. This ratio can change drastically from year to year. A drought of more than one year may cause serious die-back which will alter the rate of spread classification of large areas.

The normal drying effect of the summer sun, low humidity, and lack of precipitation gradually lowers the moisture content of both green and dead materials, large and small; it will also lower the soil moisture content and water table.

These factors and many more all contribute to the cumulative worsening of burning conditions as the fire season progresses. They should be given consideration in estimating the current fire situation.

II. EFFECTS OF CURRENT WEATHER ON FIRE BEHAVIOR

Cumulative effects set the stage for the fire season. Current weather can either intensify or reduce this over-all level of danger.

A. Precipitation.

Precipitation raises the relative humidity and raises the fuel moisture. Both of these mean that a flame uses up a great deal of energy in vaporizing this moisture before the fuel temperature can be brought up to the ignition point. Then fire intensity is reduced, rate of spread is reduced, and spotting is reduced. Lack of precipitation, of course, creates just the reverse set of conditions.

Precipitation has a much greater influence in the open than under a heavy canopy. In the open, fuel moistures are raised rapidly, only to dry out rapidly when the sun comes out. Adjacent fuels under a canopy may not even be wetted by a rainfall of 1/4 inch or less, except for a small increase of moisture due to higher humidity; however, if they do become wet, they dry out much slower than fuels in the open. Thus behavior of a fire will fluctuate much faster due to precipitation in the open than in the woods.

A given amount of precipitation may saturate a stand of grass or litter and cause an entire fireline to go out; the same amount of moisture may merely temporarily slow a fire down in heavy fuels or duff.

B. Relative Humidity.

Fires burn faster and more intensely in dry air than in wet air. There are two primary reasons for this:

(1) Fuels in dry air will not hold much moisture, and fuels in wet air will hold lots of moisture.

(2) A lot of heat energy is consumed in the process of decreasing the air moisture before the air temperature can be raised to a high degree; dry air will not have to absorb as much heat as wet air.

Hot gases are more likely to form in extremely dry air than in wet air. There is some indication that a fire may really shift into high gear when the relative humidity decreases to less than 7 or 8 percent. A close watch of the trend of humidity can give one an excellent warning of critical fire behavior. Relative humidity can be expected to change very rapidly in early morning and early evening. It can unexpectedly change very rapidly at any time during the 24 hours. This can often be predicted, but not always. A change from low to high humidity can be utilized to get some good "licks" in on one of the tougher sectors of a fire. A change from high to low humidity can be ample reason to pull crews off of a dangerous sector.

C. Fuel Moisture.

(Vu Chart, Log cross sections) IV-3b

Fuel moisture is not a basic weather factor. It is, however, a criterion of the summation effects of the total weather picture, except perhaps for wind. Fine fuels react more rapidly to weather changes. Heavy fuels reflect the entire season; their surface reflects the daily variation.

The effect of precipitation and relative humidity on fire behavior is primarily through their influence on fuel moisture.

Dry fuels do not mean that blowup conditions exist. It is a rare case, however, when dangerous fire behavior occurs in fuels having moderate moisture contents. An unexpected run can be made when a fire breaks over from a north exposure to a south exposure, or from under a timber stand into the open. A partial explanation can be increased wind, but the other explanation is a change from moderate to extremely dry fuels.

Spotting trouble is much greater in dry fuels than in moist fuels. Sufficient spotting will help a fire start rolling and going forward by leaps and bounds. Difficulty from heat radiation by the fire is also closely associated with the moisture content of the fuels.

Extremely dry fuels can literally be the "tinderbox" to combine with other critical weather factors to cause an ordinary fire to become a major blaze. Heavy concentrations of fuels are not necessary.

As mentioned earlier, green fuels may not be nearly as fireproof as a glance might indicate. Small dead material or old growth live material can carry fire just as well whether found in the woods, in a brush stand, or in a sagebrush flat. Some green fuels pack a double wallop; not only may they be dry, but the leaves are coated with wax or impregnated with volatile oils.

D. Wind Direction and Velocity.

Wind is a bad actor in relation to fire behavior. So many factors can cause abrupt changes in its direction or velocity. A lack of adequate knowledge or lack of observation can make these changes become "unpredicted" or "freak" winds.

1. Direction.

Wind will cause a fire to travel in some general direction. Assuming a uniform velocity, the intensity and rate of spread will be determined by the type and conditions of fuels ahead, and the topography ahead.

Upslope winds will augment the natural tendency for a fire to travel upward.

Vu Chart IV-3c

Downslope winds may help force a fire downward. Or it may cause fire whirlwinds which can send a fire off in a number of different directions and with varying rates of spread. The topography must be evaluated in order to outguess such happenings.

Vu Chart IV-3d

A combination of surface winds with winds aloft may cause a fire to "roll".

2. Velocity, surface.

The intensity of behavior of a fire is, in general, in direct relationship with the surface wind velocity. Wind supplies oxygen to the fuels; it bends the flame closer to adjacent fuels; it may cause a fire to burn hot enough to generate its own wind and weather. A strong wind can easily cause a fire to burn against its normal topographic tendency.

Since air movement is affected by topography, so is fire behavior. A moving fire will alter its behavior as it approaches topographic changes, since topography may change the wind direction and velocity.

3. Velocity, aloft.

The velocity of winds aloft can have various effects on fire behavior.

a. Subsidence conditions, with their winds and low humidity, are a result of air movement aloft.

b. High velocity upper winds may prevent a fire from forming a chimney effect.

c. Low velocity upper winds accompanied by moderate to high surface winds can create chimneys, erratic behavior and direction tendencies of a fire.

To determine many of these wind patterns, one must rely on the forecaster. But keeping a careful eye on the smoke column and presence of cloud types will help tip the fire control officer off as to what may happen and thus aid him in avoiding an "unexpected" blowup.

E. Atmospheric Stability.

(4 sketches, smoke columns)

IV-3e thru h

Calm stable air is not conducive to erratic fire behavior. Unstable air can cause fires to do many strange things. In the majority of unstable situations the condition is one of rising air due to steep temperature lapse rate. If enough moisture is present in the air cumulus clouds may form; observation of this will give warning. If clouds do not form, information from the forecaster should be relied upon. And again, observe the smoke column. If the smoke rises lazily and if there is no sharp stratification, then the lapse rate is slightly less than a dry adiabatic, but without inversions. This is stable air. Sharply marked tops of smoke columns or layers indicate temperature inversion. If the inversion is at the gradient wind level, then the smoke will stream off under influence of the gradient wind. A dry or super adiabatic lapse rate will cause the smoke to rise rapidly to great heights and perhaps form a chimney; this may create strong variable surface winds which can push a fire in almost any direction. In some cases involving precipitation from high-based cumulus clouds air which is colder than the environment is developed. This air is unstable, but it tends to sink and accelerate in sinking. Such air is particularly dangerous because it may push a fire almost without regard to topography.

F. fect of Clouds and Thunderstorms.

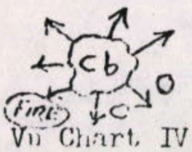
(Slide-Acl)
(Slide-Acc)

In general, clouds themselves do not affect fire behavior. They are merely indicators of air and moisture activity. Lenticular clouds and fast-moving cirrus indicate high velocity winds aloft. Altocumulus castellatus are a reminder that the air is unstable and that thunderstorms may develop later in the day.

(Slide - Cb w/virga)

(Sketch -)

Thunderstorms themselves do influence fire behavior directly. The downdrafts from a fully-developed thunderhead blow outward on the ground surface in all directions, greatest in advance of the cloud. A thunderhead passing by the side of a fire may blow it in 3 different directions within a half-hour.



Vu Chart IV-3i

G. Normal changes in Fire-Weather during a 24-hour period, and the effect of these changes on fire behavior.

At night a fire will lie down or travel slowly downhill. This is due to higher humidities and fuel moisture, and the usual cool downslope winds. In the thermal belt this night time influence is minimized, and a fire may continue to burn briskly.

In the early morning a fire will pick up on an east slope much sooner than on a west slope. This is due to earlier heating, commencement of upslope winds, and lowering of humidity and fuel moistures.

(Sketch showing the 4 periods)
Vu Chart IV-3j

During the day the general burning period is experienced from 10 AM to 5 or 6 PM. Upslope winds increase on all slopes, temperatures generally rise and humidities and fuel moisture drop. Thermal air movement increases all day long. The 10 AM control time objective is based on this sequence of weather. If a fire cannot be held at 10 AM it probably cannot be held at all until that night, or the following morning.

Conditions have already eased up on east slopes by early evening due to being in the sun's shadow. Gradually as night falls all the weather factors become less critical; the last strongholds will be the southwest and west slopes. Except, of course, for the thermal belt.

Some disastrous weather combinations have occurred at this time of day, however. Differences in pressure gradient between the cool east slope and the still warm west slope can cause the warmer air to whistle through passes and canyons and cause a fire to go crazy. This is particularly so when the prevailing wind augments this evening inversion wind.

SUMMARY

Evaluation of weather as it affects fire behavior becomes a complex problem. Some factors can be measured and some can be estimated, but many factors dealing with the upper atmosphere can only be determined by the fire-weather forecaster.

Most weather factors are interrelated with all the other factors. One cannot memorize how each combination of weather, fuels, and topography is going to affect the behavior of any single fire. A good understanding of the basic principles is essential; then one can size up a situation, apply his knowledge of the principles involved, and then take the proper steps to outmaneuver old Mother Nature.

(<u>Note</u>: This lesson condensed from former 2 hour lesson. Instructor should check time of presentation.)

U. S. DEPARTMENT OF AGRICULTURE
Forest Service

INSTRUCTOR'S LESSON PLAN

SUBJECT: FIRE BEHAVIOR	INSTRUCTOR: TOM QUINN
TITLE OF LESSON: FACTORS ASSOCIATED WITH	FILE NO.
EXTREME FIRE BEHAVIOR	DATE: MARCH 18, 1971
LENGTH OF LESSON: 2 HOURS	NO. ASSISTANTS:
METHOD OF INSTRUCTION: LECTURE	
PLACE: FORT COLLINS, COLORADO	
TRAINING AIDS:	
NUMBER IN AUDIENCE: 60	

OBJECTIVE: TRAINEES WILL LEARN SOME OF THE CHARACTISTICS OF EXTREME OR ERRATIC FIRE BEHAVIOR AND WILL BE ABLE TO APPLY THIS KNOWLEDGE DURING ANY FIRE SUPPRESSION ACTIVITY.

TIME	LESSON OUTLINE	AIDS & CUES
	INTRODUCTION	
	DURING THIS COURSE YOU HAVE REVIEWED THE FUEL, TOPOGRAPHIC AND WEATHER FACTORS THAT INFLUENCE FIRE BEHAVIOR. DURING THIS SESSION, I WANT TO EMPHASIZE THE FACTORS FOR YOU THAT CAUSE THE CONDITIONS FAVORABLE FOR FIRE BLOW-UP.	
	YOU HAVE ALL READ OR HEARD THE STORIES OF THE DISASTER FIRES OF THE PAST. THE RECENT FIRES OF CALIFORNIA AND IDAHO THAT BLEW UP AND COST MANY MEN THEIR LIVES IS THE GRIM REASON FOR YOU AS FIREMEN TO LEARN ALL YOU CAN ABOUT THE BLOW-UP AND WHAT CAUSES IT.	
	THIS IS THE OBJECTIVE OF THIS COURSE	SHOW OBJECTIVE ON VUGRAFT No. 1
	FIRST, LET'S DEFINE "BLOW-UP"	VU-GRAFT No. 2
	A SUDDEN INCREASE IN FIRE INTENSITY OR RATE OF SPREAD SUFFICIENT TO PRECLUDE DIRECT ATTACK OR CONTROL. USUALLY ACCOMPANIED BY VIOLENT CONVECTION, FIRE WHIRLS OR OTHER CHARACTERISTICS OF A FIRE STORM.	

TIME	LESSON OUTLINE	AIDS & CUES

IN THE MORE INTENSE FIRES, THE CHAIN LIKE NATURE OF COMBUSTION PROCESS IS GREATLY STRENGTHENED. IN THE BLOW-UP FIRES, THE CHAIN BECOMES SO STRONG THAT OUR PRESENT FIRE FIGHTING FORCES ARE OFTEN HELPLESS TO CONTROL THE ENERGY PRODUCED. THE BASIC PRINCIPLES OF FORE BEHAVIOR EMPHASIZE: (1) THAT COMBUSTION IS A CHAIN REACTION PROCESS WHICH TAKES PLACE AT HIGH TEMPERATURES: AND (2) THAT HEAT IS THE MOST IMPORTANT COMBUSTION PRODUCT FROM THE FIRE BEHAVIOR STANDPOINT. THEREFORE, THE HEAT PRODUCED BY BURNING FUEL IS THE MOST IMPORTANT FACTOR TO UNDERSTAND AND MANAGE IN FOREST FIRE CONTROL.

ONLY A SMALL NUMBER OF FIRES THAT OCCUR BLOW-UP, BUT THEIR IMPORTANCE FAR OUTWEIGHS THEIR NUMBER BECAUSE:

(1) THEIR HIGH INTENSITY, HIGH RATE OF SPREAD, AND OFTEN ERRATIC UNPREDICTABLE BEHAVIOR MAKES THEM A NUMBER ONE PROBLEM IN PERSONNEL SAFETY.

(2) A LARGE PART OF THE TOTAL AREA BURNED OVER A LONG PERIOD OF TIME, AND AN EVEN LARGER PART OF THE DAMAGE, IS CAUSED BY THE RELATIVELY SMALL PERCENT OF ALL FIRES.

(3) THE SUPPRESSION COST OF LARGE FIRES IS HIGH.

FOR THESE REASONS IT IS IMPERATIVE, IN SUCCESSFUL FIRE CONTROL, THAT WE RECOGNIZE AS EARLY AS POSSIBLE, WHEN POTENTIAL BURNING CONDITIONS ASSOCIATED WITH EXTREME FIRE BEHAVIOR ARE DEVELOPING OR ALREADY EXIST.

TIME	LESSON OUTLINE	AIDS & CUES

PRESENTATION:

THERE ARE 2 KEY FACTORS THAT INFLUENCE BLOW-UP.

1. FUELS
2. WEATHER FACTORS

TOPOGRAPHY IS ALSO A FACTOR, BUT IS VERY COMPLEX TO EVALUATE BECAUSE FIRES, UNDER EXTREME CONDITIONS, WILL CONTRADICT BASIC PRINCIPLES BY:

1. BURNING DOWNSLOPE
2. BURNING ACROSS DRAINAGES
3. SPREADING RAPIDLY ON FLAT TERRAIN.

NEVER FORGET TO EVALUATE THE TERRAIN DURING ANY FIRE SITUATION BUT KEEP IN MIND THAT THE OTHER MORE POWERFUL FORCES MAY OVER RIDE THE TOPOGRAPHY.

WARNING SIGNALS OF POTENTIAL EXTREME FIRE BEHAVIOR — VU-GRAFT No. 3

1. FUELS

A. LOW FUEL MOISTURE CONTENT (UNDER 25%- VERY CRITICAL UNDER 5%)

B. LARGE AMOUNTS OF FINE AND CONTINUOUS FUEL ON SLOPES.

C. CROWN FOLIAGE DRIED BY PREVIOUS FIRES OVER LARGE AREA.

D. BRUSH AND CONIFER FOLIAGE DRIED BY PROLONGED DROUGHT (ALSO FROST AND INSECT EFFECTS).

E. SNAG CONCENTRATIONS

F. HIGH BURNING INDEX AND BUILD-UP INDEX.

TIME	LESSON OUTLINE	AIDS & CUES

2. WEATHER INDICATORS → VuGRAFT No. 4

A. STRONG SURFACE WINDS, LOW WINDS ALOFT. WIND SPEED BECOMES CRITICAL ABOVE 18 M.P.H.

B. UNEXPECTED CALM. WINDS MAY SHIFT AND BECOME STRONGER SUPPLYING MORE OXYGEN TO THE FIRE.

C. HIGH FAST MOVING CLOUDS -- MAY RESULT IN UNUSUAL WINDS ON THE GROUND AND DOWNDRAFTS.

D. HIGH EARLY MORNING TEMPERATURE.

E. DUST DEVILS OR WHIRLWINDS

F. THUNDERHEADS (STRONG WIND BEFORE AND DOWNDRAFT)

g. SMOKE COLUMN DIRECTION AND SHAPE (FRACTURED COLUMN WILL INTENSIFY SPOTTING.)

H. BUMPY FLYING -- TURBULENT ATMOSPHERE.

I. FRONTAL ACTIVITY -- RESULTS IN WIND CHANGES AND INCREASES THE WIND SPEEDS.

J. INVERSION LAYER - FIRE WILL LAY QUIET UNTIL FIRE OR SMOKE BREAKS THROUGH.

K. TOPOGRAPHY INFLUENCED BY WEATHER → VuGRAFT No. 5

1. PASSES AND SADDLES MAY RESULT IN HORIZONTAL EDDIES ON LEE SIDE OF RIDGE.

2. LEE SIDE OF MOUNTAINS: VERTICAL EDDIES WILL BE PRODUCED BY GRADIENT WINDS.

3. RIDGE TOPS - FIRE MAY BURN UPSLOPE AND CHANGE BEHAVIOR AS IT MOVES FROM EFFECT OF LOCAL WIND TO EFFECT OF GRADIENT WIND.

TIME	LESSON OUTLINE	AIDS & CUES

4. STEEP SLOPES AND CANYONS CAN CAUSE FAST INTENSE RUNS.

5. THERMAL BELTS - CAN CAUSE HIGH INTENSITY BURNING AT NIGHT.

3. FIRE BEHAVIOR

→ VUGRAPH No. 6

A. CONVECTION COLUMNS INDICATOR OF AND UNSTABLE CONDITION.

B. SPOTTING

C. INTENSE BURNING INSIDE FIRE.

D. TREE OR BRUSH TORCHING OUT.

E. FIRE WHIRLWINDS.

NOW LETS LOOK A LITTLE MORE IN DEPTH AT THESE CHARACTERISTICS OF EXTREME FIRE BEHAVIOR.

1. A RAPID BUILDUP OR GROWTH OF INTENSITY AFTER A FIRE REACHES A CRITICAL RATE OF ENERGY OUTPUT.

A. AS THE RATE OF FUEL CONSUMPTION INCREASES, THERE IS A DISTINCT PROBABILITY OF A BLOW-UP FIRE, BECAUSE:

(1) THE AMOUNT OF AVAILABLE FUEL INCREASES. THAT IS, INCREASED HEAT DRIES OUT MORE FUELS FASTER AND THEIR ENGERY YIELD IS ADDED TO THE TOTAL ENERGY.

(2) THE RATE OF SPREAD INCREASES.

(1) x (2) = RATE OF FUEL CONSUMPTION.

(3) CRITICAL BURN OUT TIME INCREASED, THUS INCREASING TOTAL HEAT. CRITICAL BURNOUT TIME IS DEFINED AS THE MAXIMUM LENGTH OF TIME THAT A FUEL CAN BURN AND STILL

TIME	LESSON OUTLINE	AIDS & CUES
	BE ABLE TO FEED ITS ENERGY INTO THE BASE OF THE CONVECTION COLUMN.	
	B. PROBABILITY OF BLOW-UP INCREASES RAPIDLY WITH INCREASING SIZE OF "HOT AREA". REFER TO ATTACHEMENT #1 FOR CHART.	→ VUGRAFT No. 7
	2. A HIGH SUSTAINED RATE OF SPREAD.	
	THE SUSTAINED FORWARD RATE OF SPREAD MAY BE AS MUCH AS 1.5 TO 3.0 MILES PER HOUR IN FLAT OR SLIGHTLY ROLLING COUNTRY. THE SUSTAINED RATE OF SPREAD AVERAGES LESS FOR MOUNTAINOUS COUNTRY, AS MOUNTAINS USUALLY TEND TO SLOW DOWN THE OVERALL SPREAD OF A LARGE FIRE, EXCEPT THAT UPSLOPE SPREAD MIGHT EXCEED A RATE OF 3.0 MILES PER HOUR.	
	DEPENDING ON THE FUEL SUPPLY, THE HIGH SUSTAINED RATE OF SPREAD MAY LAST FOR SEVERAL HOURS. OFTEN DURING THIS PERIOD THERE MAY BE BURSTS OF SPREAD DURING WHICH THE FIRE MAY ADVANCE $\frac{1}{4}$ MILE IN A FEW MINUTES. THE RATE OF AREA BURNED MAY EXCEED 1000 ACRES PER HOUR, BUT SELDOM DOES IT EXCEED 3000 ACRES PER HOUR.	
	3. A WELL DEVELOPED CONVECTION COLUMN IS A DISTINCTIVE FEATURE OF BLOW-UP FIRES. THE COLUMN MAY BE THE TOWERING TYPE, WHICH REACHES UPWARDS FOR THOUSANDS OF FEET WHEN THE UPPER WINDS ARE LOW. IF STRONGER WINDS PREVAIL IN THE UPPER LEVELS, THE COLUMN WOULD BE OF THE FRACTURED TYPE, AS HIGH WINDS SHEAR OFF THE TOP OF THE COLUMN.	→ SLIDES OF CONVECTION Column BUILDING TO MATURE

TIME	LESSON OUTLINE	AIDS & CUES

4. LONG DISTANCE SPOTTING (600 FEET OR MORE).

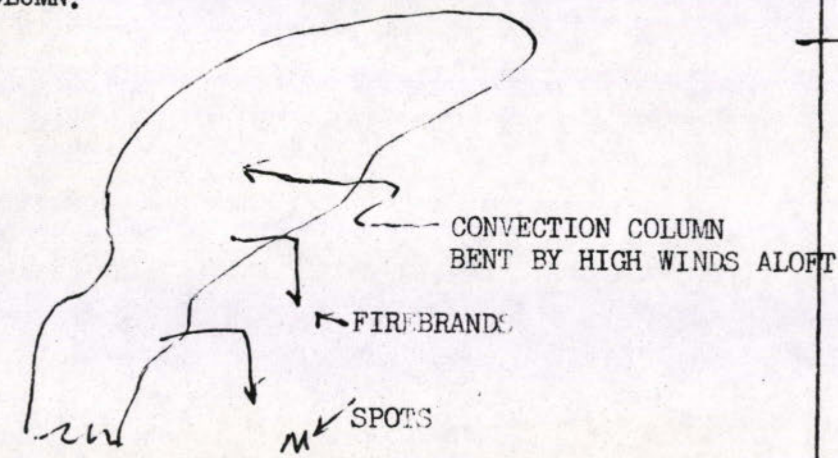
A. MOST IMPORTANT FACTOR IN HIGH RATES OF SPREAD.

B. DISTANCE: ½ MILE COMMON: OCCASIONALLY 2-3 MILES.

C. EMBERS ARE CARRIED ALOFT IN UPDRAFT OF CONVECTION COLUMN, POSSIBLY TO AN ALTITUDE OF 5000'.

(1) MAY BE THROWN IN DIRECTION OF FRACTURED CONVECTION COLUMN.

→ DRAW ON BLACK BOARD



(2) FIREBRANDS ARE MOST COMMONLY DROPPED AHEAD AND ON RIGHT SIDE OF FIRE. MORE COMPLEX WITH LOCAL SLOPE EFFECTS, AS SLOPE CAN ALTER SURFACE WIND CONDITIONS.

5. FIRE WHIRLWINDS.

A. DEVELOPED WITHIN THE FIRE ITSELF: PROBABLY DUE TO COMBINATION OF (1) EXTREME HEAT OF FIRE, AND (2) EXTREME TURBULENCE OF WELL DEVELOPED CONVECTION COLUMN.

(1) LARGER ONES APPEAR TO FORM AT HEAD OF FIRE WHERE GREATEST HEAT AND TURBULENCE EXIST.

(2) SMALLER ONES IN HEATED AREA BEHIND FIRE FRONT.

(3) SOME DEVELOP HIGH IN CONVECTION COLUMN, AND MAY CONTRIBUTE TO LONG DISTANCE SPOTTING.

TIME	LESSON OUTLINE	AIDS & CUES
	B. CONDITIONS OF DEVELOPMENT.	
	(1) HEAT SOURCE.	
	(2) NO HIGH WIND VELOCITY TO SHEAR DEVELOPING COLUMN.	
	(3) TRIGGERING MECHANISM TURBULENCE OF SOME KIND, EDDIES, DISCONTINUITY OF WINDS.	
	C. NOT TOO MUCH KNOWN ON HOW, WHEN, OR WHY THEY FORM.	
	D. SIZE - VARIES UP TO 500' IN DIAMETER. SMALL ONES JUST AS DANGEROUS AS LARGE ONES AS FAR AS SPREADING FIRE IS CONCERNED.	
	E. CONTRIBUTE TO RAPID SPREAD BY STARTING FIRES AHEAD OF FIRE FRONT.	
	F. SERIOUS SAFETY FACTOR, AS THEY MAY LEAVE LINE ANY WHERE AND ENDANGER LIVES OF FIREFIGHTERS WITH FIRES THEY SPREAD, OR WITH THE HOT DEBRIS THEY CARRY.	
	6. HORIZONTAL FLAME SHEETS.	
	A. RARE AND OF SHORT DURATION - RARELY EXTEND TO MORE THAN 150 FEET. OBSERVERS HAVE REPORTED 30 FOOT FLAMES SUDDENLY TILTED FORWARD SO AS TO BE NEARLY HORIZONTAL.	
	B. FLAMES ARE TILTED FORWARD BY "JET" ACTION OF DOWN DRAFTS.	
	C. SAFETY HAZARD.	
	7. WHEN FIRES HAVE REACHED SUCH AN INTENSITY THAT THEY EXHIBIT CHARACTERISTICS DESCRIBED ABOVE, THE COMBUSTION CHAIN HAS USUALLY BECOME SO STRONG THAT IT CANNOT BE BROKEN BY CONVENTIONAL FIREFIGHTING METHODS.	

TIME	LESSON OUTLINE	AIDS & CUES

NOW LETS TAKE A CLOSER LOOK AT THE FACTORS THAT CONTRIBUTE TO THE EXTREME FIRE BEHAVIOR.

1. FUELS

A. SUPPLY

(1) FUEL IS OF PRIMARY CONCERN IN FIRE CONTROL BECAUSE IT IS THE FIRE'S ENERGY SOURCE, AND THE BASIC ELEMENT NEEDED FOR COMBUSTION. WEATHER AND TOPOGRAPHY ASSUME SIGNIFICANCE ONLY IN RELATION TO THE EXISTING FUEL SUPPLY.

(2) SIZE, CONTINUITY, AND ARRANGEMENT OF FUEL ALL AFFECT COMBUSTION RATE AND HENCE FIRE INTENSITY.

(3) THE GREATER THE VOLUME OF AVAILABLE FUEL, THE MORE HEAT WILL BE CREATED, AND THE GREATER WILL BE THE INTENSITY POTENTIAL.

B. HIGH FUEL FLAMMABILITY.

(1) RELATIVE DRYNESS IS GOVERNING FACTOR IN EASE OF IGNITION AND IN THE AMOUNT OF TOTAL FUEL VOLUME THAT WILL BE CONSUMED, ADDING TO HEAT ENERGY YIELD OF FIRE.

(2) AVAILABLE FUEL, ENERGY, AND FIRE INTENSITY INCREASE WITH DECREASING FUEL MOISTURE CONTENT. AVAILABLE FUEL (I.E., FUEL THAT WILL ACTUALLY BURN AND CONTRIBUTE TO FIRE INTENSITY) DEPENDS ON

(A) FUEL

(b) FUEL TYPE

(C) WIND VELOCITY

(D) SLOPE

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2. WEATHER FACTORS.

A. STABILITY OF THE ATMOSPHERE.

(1) THE TENDENCY OF THE ATMOSPHERE IS TO RESIST VERTICAL MOTION.

(2) INSTABILITY CAUSES THERMAL TURBULENCE, OR IRREGULAR MOTION OF THE AIR.

(3) DIRECT EFFECTS OF TURBULENCE (MOST EVIDENT DURING THE AFTERNOON HOURS WHEN INSTABILITY IS GREATEST):

(A) GUSTY AND VARIABLE SURFACE WINDS, ESPECIALLY IN THE VICINITY OF FIRES.

(B) SPOTTING FROM WHIRLWINDS AND LOCAL UPDRAFTS.

(C) TENDENCY FOR FIRE TO CROWN READILY.

(D) TENDENCY FOR FIRE TO TRAVEL RAPIDLY UPSLOPE IN VARYING DIRECTIONS.

(4) THESE EFFECTS ARE GREATEST ON SMALL FIRES. LARGE FIRES TEND TO OVERCOME LOCAL ATMOSPHERE TURBULENCE AND CREATE THEIR OWN TURBULENCE AND BURNING CONDITIONS.

B. INVERSIONS.

(1) A FIRE MAY BE BURNING QUIETLY BENEATH AN INVERSION. IF THE CONVECTION COLUMN BREAKS THROUGH THE INVERSION LAYER, FIRE INTENSITY MAY INCREASE BECAUSE OF A CHIMNEY EFEECT AND FIRE MAY BLOW-UP.

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(2) IF A FIRE IS BURNING QUIETLY ON A SLOPE JUST BENEATH AN INVERSION, IT MAY INTENSIFY IF THE FIRE ITSELF BURNS UPSLOPE THROUGH THE ELEVATION OF THE INVERSION. (NOT USUAL.)

C. ADVERSE WIND CONDITIONS.

(1) DECREASE OF WIND WITH HEIGHT ABOVE A FIRE PERMITS THE FIRE TO DEVELOP A CONVECTION COLUMN AND CREATE "CHIMNEY" EFFECT.

(2) HEAT ENERGY IS CONVERTED TO TURBULENT ENERGY WHICH DRIVES FIRE TO AN INCREASING INTENSITY - THE BLOW-UP PROCESS.

D. EDDIES.

(1) CREATED BY ATMOSPHERIC OR MECHANICAL TURBULENCE.

(2) HORIZONTAL EDDIES WILL FORM NEAR PASSES OR EDDIES ON LEE SIDES OF RIDGES.

→ DRAW ON BLACK BOARD

(3) VERTICAL EDDIES WILL FORM ON LEE SIDES OF RIDGES OR AROUND OTHER LARGE OBSTRUCTIONS.

→ DRAW ON BLACKBOARD

(4) AS FIRES BURN TO RIDGE TOPS, THEY MAY BE HIGHLY AFFECTED BY EDDIES AND CAUSE ERRATIC FIRE BEHAVIOR.

(VU GRAPH SLIDE: WEATHER AND FIRE BEHAVIOR IV-4a)

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E. WINDS FROM CUMULUS CLOUDS.

(1) A FIRE MAY BE BEHAVING IN A NORMAL MANNER UNDER THE EXISTING BURNING CONDITIONS. IF A CUMULUS TYPE CLOUD (CUMULUS, CUMULONIMBUS) WHICH HAS DEVELOPED STRONG DOWNDRAFTS (CAUSED BY VIRGA FALLING FROM BASE OF CLOUD) MOVES OVER THE FIRE, IT MAY CREATE STRONG LOCAL WINDS AND CAUSE THE FIRE TO SPREAD RAPIDLY IN SEVERAL DIRECTIONS. EXPECTED WINDS FROM THIS CONDITION:

(A) AS CLOUD APPROACHES, SURFACE WINDS WILL BE IN DIRECTION OF MOVEMENT OF THE CLOUD.

(B) AS CLOUD PASSES OVER FIRE, SURFACE WINDS WILL BE LATERAL IN BOTH DIRECTIONS.

(C) AS CLOUD MOVES BEYOND FIRE, SURFACE WINDS WILL BE IN DIRECTION OPPOSITE TO DIRECTION OF MOVEMENT OF CLOUD.

(2) STRONGEST SURFACE WINDS ARE FOUND AS CLOUD APPROACHES.

(3) EFFECT VARIES FROM 1-5 MILES DEPENDING ON HEIGHT OF CLOUD BASE ABOVE FIRE AND ITS LOCATION RELATIVE TO FIRE.

(4) THERE ARE ALSO UPDRAFTS AS CUMULUS CLOUDS ARE BUILDING, BUT THESE EFFECTS ARE NOT NORMALLY EXPERIENCED ON THE GROUND AND ARE NOT AS IMPORTANT NOR AS PRONOUNCED AS DOWNDRAFTS FROM MATURE CUMULUS.

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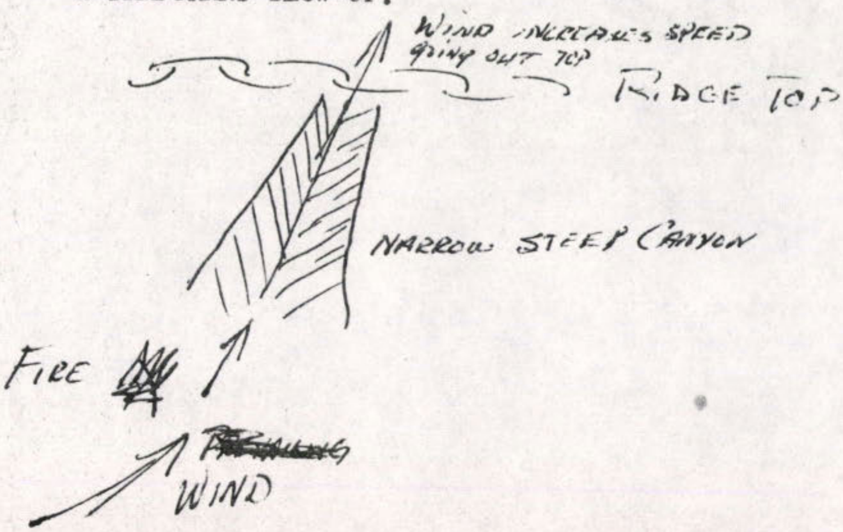
F. SUBSIDENCE.

(1) UNDER CERTAIN CONDITIONS, COLD, DRY AIR FROM EXTREMELY HIGH ALTITUDE - MAY BEGIN TO SUBSIDE OR DESCEND. AS THIS AIR SUBSIDES, IT INCREASES IN TEMPERATURE BUT CANNOT PICK UP ANY MOISTURE SO IT CONTINUES TO LOWER. AS THIS SUBSIDING AIR NEARS THE GROUND, THE BURNING CONDITIONS MAY BECOME SEVERE: I.E., LOW HUMIDITIES, AND HIGH TEMPERATURES. THIS LOWERS FUEL MOISTURE TO CRITICAL LEVELS. REMEMBER THOUGH, THAT SUBSIDENCE IS A LONG TERM PROCESS, IT DOES NOT NORMALLY OCCUR IN A MATTER OF HOURS.

(2) SUCH CONDITIONS MAY CAUSE DIFFICULTY TO CONTROL A GOING FIRE, AND FIRE INTENSITY MAY BUILD UP RAPIDLY.

3. TOPOGRAPHY.

A. CHIMNEYS - IF A SPREADING FIRE REACHES A NATURAL TOPOGRAPHIC CHIMNEY (NARROW BOX CANYON WITH STEEP SLOPES), IT MAY BURN RAPIDLY OUT THE TOP OF THE CANYON, CAUSING A TEMPORARY BLOW-UP.



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B. LEE SIDES OF MOUNTAINS.

CAUSE EDDIES AND TURBULENT CONDITIONS WHICH MAY CAUSE FIRE TO BLOW-UP. LEE SLOPES FAVOR WHIRLWIND DEVELOPMENT ALSO.

C. THERMAL BELT.

(1) AREA OCCUPYING APPROXIMATELY THE MIDDLE THIRD OF A MOUNTAIN SLOPE. HERE THE AIR TEMPERATURE DOES NOT DROP AS MUCH AT NIGHT AS IT DOES IN LOWER ALTITUDES: HENCE DURING THE NIGHT TEMPERATURES ARE HIGHER AND RELATIVE HUMIDITY LOWER IN THE THERMAL BELT THAN AT LOWER ALTITUDES ON THE SLOPE. THEREFORE, FUELS WILL REMAIN RELATIVELY DRY. FIRES BURNING IN THE THERMAL BELT WILL CONTINUE TO BURN WITH HIGH INTENSITY THROUGH THE NIGHT, ESPECIALLY THE EARLIER HOURS. FIRES BURNING RELATIVELY SLOWLY AT LOWER ALTITUDES MAY GRADUALLY SPREAD UPSLOPE INTO THE THERMAL BELT AND SUDDENLY INCREASE IN INTENSITY AND EVEN BLOW -UP.

D. NARROW CANYONS: RADIATION EFFECT ON OPPOSITE SLOPE PREDRYS FUELS. SPOTS MAY OCCUR MORE EASILY BECAUSE OF FIRE BRANDS.

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4. CHANGES IN FIRE ENVIRONMENT.

(A) FIRE ENVIRONMENT: THE CONDITIONS OF FUEL, WEATHER, AND TOPOGRAPHY UNDER WHICH A FIRE BURNS.

(B) GREATEST DIFFERENCES OCCUR BETWEEN AN OPEN AND A CLOSED CANOPY OF VEGETATION.

(1) CLOSED ENVIRONMENT: CAN BE THOUGHT OF AS BEING BENEATH A CONOPY OF COVER TYPE. ESSENTIALLY HAS SURFACE WEATHER CONDITIONS.

(2) OPEN ENVIRONMENT: CAN BE THOUGHT OF AS BEING ABOVE THE CANOPY OF COVER TYPE. ESSENTIALLY HAS UPPER AIR WEATHER CONDITIONS.

	CLOSED	OPEN
TEMPERATURE	80	90
FUEL MOISTURE	7	3
WIND	4	12
HUMIDITY	25	15
BURNING INDEX	9	48

← VuGRAFT No. 8

(C) A CLEAR CUT AREA PRODUCES A GREAT CHANGE IN ENVIRONMENT. THIS FACTOR COMBINED WITH THE ADDITIONAL SLASH FUEL PRODUCES A COMBINED EFFECT ON FIRE BEHAVIOR TO CAUSE LARGER FIRES.

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D. WIND CHANGES ARE PRODUCED BETWEEN CLOSED AND OPEN ENVIRONMENTS. IN AN OPEN ENVIRONMENT, THE SURFACE IS RELATIVELY WARM AND WINDS ARE MORE LIKELY TO BE TURBULENT. IN A CLOSED ENVIRONMENT, THE SURFACE IS RELATIVELY COOL, PRODUCING LAMINAR, SMOOTH FLOWING WINDS.

NOW YOU, AS FIREMEN, ARE READY TO MAKE PREDICTIONS OF THE POTENTIAL BURNING CONDITIONS:

HERE IS THE SEQUENCE YOU SHOULD FOLLOW.

A. WORK OUT PROBABLE BI AND BUI FROM FIRE-WEATHER FORECAST.

B. CONSIDER FUEL MOISTURE PREDICTION AS IT MAY CONTRIBUTE TO SPOTTING.

C. CONSIDER SURFACE WINDS EXPECTED AS TO VELOCITY AND PROBABILITY OF GUSTINESS.

D. OBSERVE INDICATIONS OF TURBULENCE SUCH AS PRESENCE OF DUST DEVILS OR REPORTS OF BUMPY FLYING.

E. NOTE TEMPERATURE DEPARTURES FROM NORMAL.

F. NOTE PARTICULARLY IF MAJOR WIND SHIFTS ARE EXPECTED ASSOCIATED WITH <u>DRY COLD FRONT PASSAGE</u>.

G. IN VIEW OF ITEMS A TO F, FORM YOUR OPINION AS TO THE PREDICTED GENERAL LEVEL OF BURNING CONDITIONS IN THE IMMEDIATE FUTURE, AS COMPARED TO THE KNOWN PAST, AND ADJUST THE PRE-PAREDNESS ORGANIZATION ACCORDINGLY.

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SUMMARY

THESE ARE THE MAIN FACTORS THAT INDICATE BLOWUP CONDITIONS. THERE MAY BE OTHERS IN ANY GIVEN FIRE SITUATION. FUELS AND WEATHER ARE THE TWO KEY FACTORS DOMINATING BLOWUP CONDITIONS. TOPOGRAPHY IS AN INFLUENCE, BUT IS A VERY COMPLEX FACTOR IN A SPECIFIC SITUATION--IT ALTERS THE LOCAL WEATHER, MAINLY WIND. NO OTHER FACTOR CAN BE USED BY ITSELF, BUT BY ANALYZING A COMBINATION OF FIRE BEHAVIOR FACTORS, THE FIREMAN CAN BETTER ASSESS THE SITUATION AND MAKE ACCURATE DECISIONS FOR SAFE FIRE SUPPRESSION.

No. 1

LESSON OBJECTIVE

TRAINEES WILL LEARN SOME OF THE CHARACTERISTICS OF EXTREME OR ERRATIC FIRE BEHAVIOR AND WILL BE ABLE TO APPLY THIS KNOWLEDGE DURING ANY FIRE SUPPRESSION ACTIVITY.

A SUDDEN INCREASE IN FIRE INTENSITY OR RATE OF SPREAD SUFFICIENT TO PRECLUDE DIRECT ATTACK OR CONTROL. USUALLY ACCOMPANIED BY VIOLENT CONVECTION, FIRE WHIRLS OR OTHER CHARACTERISTICS OF A FIRE STORM.

No 3

WARNING SIGNALS OF POTENTIAL EXTREME FIRE BEHAVIOR

1. FUELS

A. LOW FUEL MOISTURE CONTENT (UNDER 25%- VERY CRITICAL UNDER 5%)

B. LARGE AMOUNTS OF FINE AND CONTINUOUS FUEL ON SLOPES.

C. CROWN FOLIAGE DRIED BY PREVIOUS FIRES OVER LARGE AREA.

D. BRUSH AND CONIFER FOLIAGE DRIED BY PROLONGED DROUGHT (ALSO FROST AND INSECT EFFECTS).

E. SNAG CONCENTRATIONS

F. HIGH BURNING INDEX AND BUILD-UP INDEX.

2. WEATHER INDICATORS

A. STRONG SURFACE WINDS, LOW WINDS ALOFT. WIND SPEED BECOMES CRITICAL ABOVE 18 M.P.H.

B. UNEXPECTED CALM. WINDS MAY SHIFT AND BECOME STRONGER SUPPLYING MORE OXYGEN TO THE FIRE.

C. HIGH FAST MOVING CLOUDS -- MAY RESULT IN UNUSUAL WINDS ON THE GROUND AND DOWNDRAFTS.

D. HIGH EARLY MORNING TEMPERATURE.

E. DUST DEVILS OR WHIRLWINDS

F. THUNDERHEADS (STRONG WIND BEFORE AND DOWNDRAFT)

g. SMOKE COLUMN DIRECTION AND SHAPE (FRACTURED COLUMN WILL INTENSIFY SPOTTING.)

H. BUMPY FLYING -- TURBULENT ATMOSPHERE.

I. FRONTAL ACTIVITY -- RESULTS IN WIND CHANGES AND INCREASES THE WIND SPEEDS.

J. INVERSION LAYER - FIRE WILL LAY QUIET UNTIL FIRE OR SMOKE BREAKS THROUGH.

K. TOPOGRAPHY INFLUENCED BY WEATHER

1. PASSES AND SADDLES MAY RESULT IN HORIZONTAL EDDIES ON LEE SIDE OF RIDGE.

2. LEE SIDE OF MOUNTAINS: VERTICAL EDDIES WILL BE PRODUCED BY GRADIENT WINDS.

3. RIDGE TOPS - FIRE MAY BURN UPSLOPE AND CHANGE BEHAVIOR AS IT MOVES FROM EFFECT OF LOCAL WIND TO EFFECT OF GRADIENT WIND.

4. STEEP SLOPES AND CANYONS CAN CAUSE FAST INTENSE RUNS.

5. THERMAL BELTS - CAN CAUSE HIGH INTENSITY BURNING AT NIGHT.

3. FIRE BEHAVIOR

A. CONVECTION COLUMNS INDICATOR OF AND UNSTABLE CONDITION.

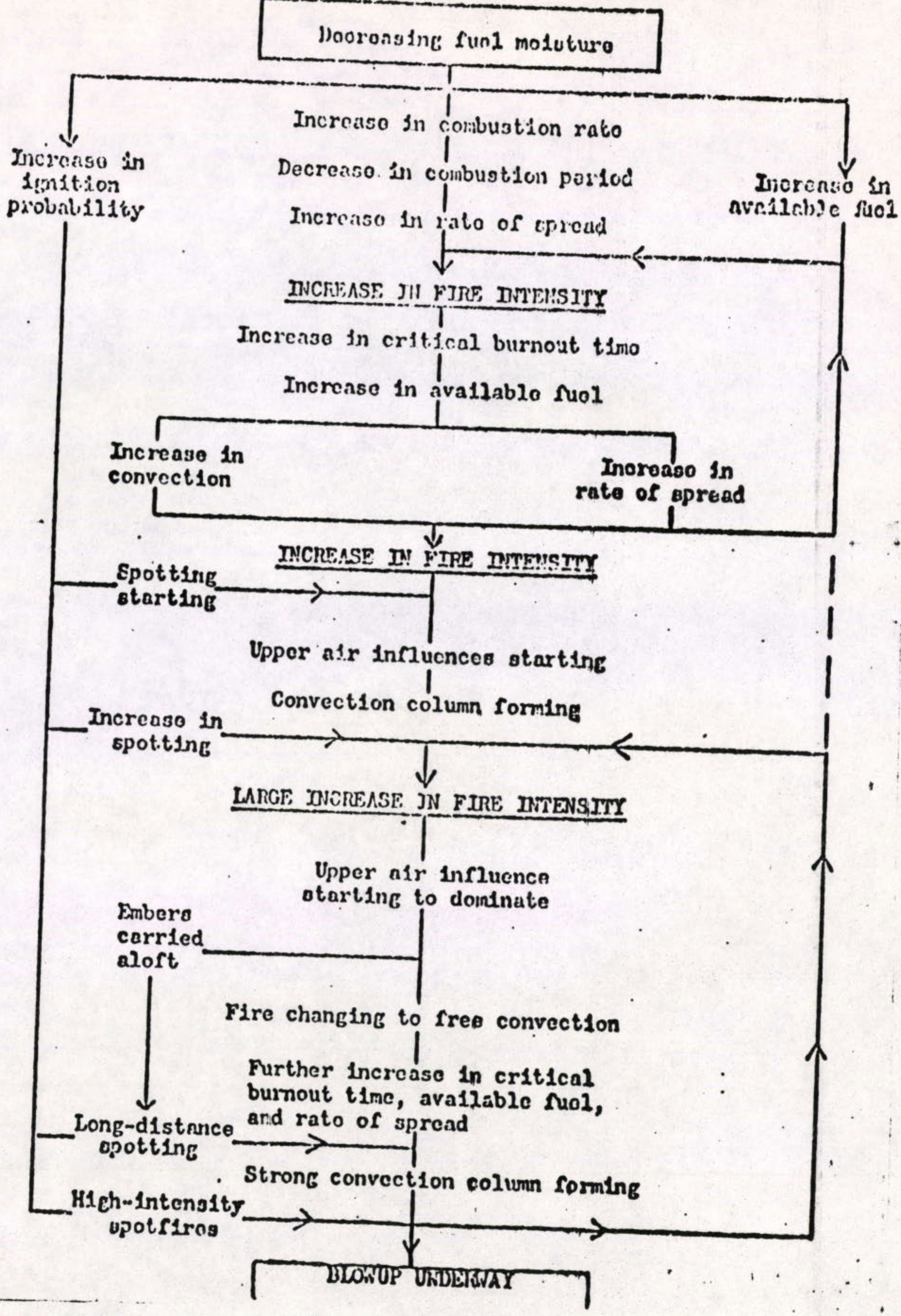
B. SPOTTING

C. INTENSE BURNING INSIDE FIRE.

D. TREE OR BRUSH TORCHING OUT.

E. FIRE WHIRLWINDS.

THE CYCLE OF REENFORCEMENT IN FOREST FIRE BEHAVIOR



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