USE OF THE AIR TANKER

AS A

FOREST FIREFIGHTING TOOL

PRELIMINARY DRAFT

A STUDY OF THE USE OF AIR TANKERS
ON FOREST FIRES IN 1959 BY THE
CALIFORNIA DIVISION OF FORESTRY

STATE OF CALIFORNIA
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ABSTRACT

THE QUESTIONS OF HOW, WHEN, AND WHERE TO USE AIR TANKERS ON FOREST FIRES MOST EFFICIENTLY AND ECONOMICALLY HAVE NOT BEEN WHOLLY ANSWERED BY FOREST FIREFIGHTING AGENCIES. IN 1959 THE CALIFORNIA DIVISION OF FORESTRY CONTINUED TO USE AIR TANKERS ON INITIAL ATTACK ON A LIMITED EXPERIMENTAL BASIS IN AN EFFORT TO REFINE ITS DISPATCH AND TACTICAL USE GUIDELINES. CONSIDERABLE PROGRESS WAS MADE AND IS REPORTED IN THIS PAPER, BUT FURTHER EVALUATION OF THE AIR TANKER PROGRAM IS RECOGNIZED AS BEING NEEDED.

Use of the Air Tanker as a Forest Firefighting Tool

Since 1956 the use of air tankers on forest fires by forest firefighting agencies has expanded greatly. Concurrent with this expansion has been the problem of how best to integrate the air tanker into existing fire control organizations. Almost at once the questions of how, when, and where to use this new tool most efficiently, effectively, and economically presented themselves for answering. Continual evaluation of the use of air tankers on forest fires has been made by the firefighting agencies in an effort to find the best answers (United States Forest Service, California Region, 1959; Winkworth, 1958; Banks, 1958; Beeman, 1958; Ely and others, 1957).

In 1959 the California Division of Forestry conducted an experiment designed to provide data which would permit the refinement of air tanker use criteria and which would expand the findings of previous years' operations (Reinecker, 1960; Phillips, 1959; Miller and Reinecker, 1957). The limited budget provided for this program allowed for contracting of a certain number of aircraft and pilots and for purchasing of fire retardant materials. Supervising and facilitating personnel had to be provided by the Division from its regular fire control forces, thus sacrificing the performance of normal duties by these people.

SUMMARY

The experiment used a basic team of four air tankers which moved throughout the fire season to three different administrative districts in the state, thus providing data of use under a variety of fire conditions, fire weather, topography, and fuel types. In addition other aircraft were used from more permanent bases throughout the state.

The activities of the tankers while in flight were controlled and directed as often as possible by drop coordinators, who were experienced fire control men and who flew in separate observation type aircraft. Personnel were provided at each airport facility to mix retardant slurry, to load aircraft during fire action, and to maintain records of air tanker use.

Data were obtained in several ways about air tanker use on forest fires and about the fires themselves. Analysis of the data resulted in the following recommendations or improvements to existing guidelines:

Tank and gate design:

1. At the present level of knowledge it is felt that tanks should be designed with no protruding lips, flanges, or other areas of entrapment. Gates should be as large as the tank bottom with no obstructions to the flow of retardant.

Central direction:

1. Since air tankers can easily range on initial attack beyond ranger unit boundaries, some degree of central direction from district headquarters must be maintained.

Pilot proficiency:

1. Minimum experience standards established in the past should be maintained.

2. PILOTS NEW TO THE FIRE CONTROL JOB WILL REQUIRE PERHAPS A MINIMUM OF 50 DROPS BEFORE THEY BECOME PROFICIENT.

3. EXTREME COMPETITION BETWEEN EXPERIENCED AND INEXPERIENCED PILOTS SHOULD BE DISCOURAGED TO PREVENT POSSIBLE ACCIDENTS.

FACILITIES:

1. ADEQUATE PERSONNEL AND FACILITIES ARE THE KEYS TO DECREASING "DOWN-TIME" OF AIRCRAFT ON A SUSTAINED FIRE CONTROL OPERATION.

2. THERE SHOULD BE A STORAGE CAPACITY OF AT LEAST 10,000 GALLONS OF RETARDANT WHERE SMALL AIR TANKERS ARE USED AND AT LEAST 30,000 GALLONS WHERE LARGE TANKERS ARE USED.

3. A TRANSFER PUMP CAPABLE OF DELIVERING 500 GALLONS PER MINUTE IS DESIRABLE.

4. MIXING AND LOADING AREAS SHOULD BE ADJACENT BUT DISTINCTLY SEPARATED. BOTH AREAS SHOULD BE PAVED, HAVE GOOD DRAINAGE, AND HAVE WATER UNDER PRESSURE FOR REMOVING SPILLED AND EXCESS RETARDANT.

5. BATCH-TYPE MIXERS SHOULD BE PLANNED FOR LARGE, PERMANENT AIR TANKER BASES.

6. BOTH OFFICE AND LOUNGING FACILITIES SHOULD BE PROVIDED AND BE SOMEWHAT SEPARATED.

7. ONLY APPROVED AIRPORTS SHOULD BE USED.

TRAINING:

1. BECAUSE OF THE COST AND TECHNICAL ASPECTS OF THE AIR TANKER PROGRAM, ALL PERSONNEL INVOLVED MUST RECEIVE TRAINING. TRAINING PROGRAMS FOR THE DIFFERENT TYPES OF PERSONNEL ARE SUGGESTED.

PLANNING AN AIR TANKER PROGRAM:

1. MANY FACTORS MUST BE CONSIDERED PRIOR TO SELECTING AIR TANKER TYPES FOR SPECIFIC LOCATIONS. AIR TANKER TYPES VARY CONSIDERABLY IN THEIR CAPACITY TO DELIVER RETARDANTS EFFECTIVELY, DEPENDENT ON FACTORS OF 1) DISTANCE TO THE FIRE, 2) TOPOGRAPHY, 3) NORMAL FIRE BEHAVIOR, ETC.

2. EACH DISPATCHER'S OFFICE SHOULD HAVE AN AIR OPERATIONS MAP WHICH WILL DELINEATE 1) THOSE AREAS WHERE AIR TANKER USE WILL ALMOST ALWAYS BE EXCLUDED, 2) THOSE AREAS WHERE TANKERS WILL ALMOST ALWAYS BE DISPATCHED ON INITIAL ATTACK, AND 3) THOSE AREAS WHERE AIR TANKERS MAY OR MAY NOT BE USED DEPENDING UPON THE COMBINED EFFECT OF SEVERAL FACTORS. AN AIR OPERATIONS MAP SHOULD ALSO INCLUDE AT LEAST THE LOCATION OF DEEP, NARROW CANYONS, POWER AND TELEPHONE LINES OVER 25 FEET IN HEIGHT, AND VEGETATIVE TYPES.

3. NO AIR TANKER PROGRAM SHOULD BE ATTEMPTED WITHOUT PLANNING AND PROVIDING AN ADEQUATE COMMUNICATIONS SYSTEM, INCLUDING A SEPARATE AIR NET.

4. CONTINUAL EVALUATION OF AIR TANKERS AND PILOTS SHOULD BE MADE TO ELIMINATE THOSE WHICH MAY BE FOUND UNDESIRABLE.

INITIAL ATTACK DISPATCHING:

1. AIR TANKERS SHOULD BE DISPATCHED THE SAME AS ANY OTHER TOOL.

2. IF CONDITIONS INDICATE THAT AIR TANKERS SHOULD BE USED, THEY SHOULD BE DISPATCHED WITHOUT DELAY.

3. AIR TANKERS ARE MOST EFFECTIVE IN GRASS AND LIGHT BRUSH, WHEN THERE ARE LIGHT OR NO WINDS, ON FLAT OR ROLLING TOPOGRAPHY, ON FIRES STARTING AFTER 1400 P.D.T., AND WHEN DISTANCE TO THE FIRE FROM THE AIRPORT IS 20 MILES OR LESS

4. AIR TANKERS ARE LESS EFFECTIVE IN DENSE BRUSH OR TIMBER, WHEN WINDS ARE OVER 20 MILES PER HOUR, ON STEEP TERRAIN, ON FIRES STARTING BETWEEN 1000 AND 1400 P.D.T., WHEN DISTANCE TO THE FIRE FROM THE AIRPORT EXCEEDS 20 MILES, AND WHEN THE AIR IS TURBULENT.

5. AIR TANKERS ARE OFTEN LIKELY NOT TO BE NEEDED WHEN THE BURNING INDEX IS BELOW 9, THE AIR TEMPERATURE IS BELOW 80°F., THE FIRE IS CONFINED TO THE GROUND IN DENSE TIMBER OR DENSE WOODLAND (ESPECIALLY ON THE SHADY SLOPE, LATE IN THE DAY), CREW GETAWAY AND TRAVEL TIME IS LESS THAN 10 MINUTES, AND WHEN FIRES STARTED FROM A WET LIGHTNING STORM IF GROUND FORCES COULD HANDLE THEM ALL WITHIN THE FIRST 24 HOURS.

AIR-GROUND COORDINATION:

1. AIR-GROUND COORDINATION IS ABSOLUTELY ESSENTIAL TO SUCCESSFUL AIR TANKER ACTIVITY.

2. AN ADEQUATE COMMUNICATIONS SYSTEM IS A NECESSITY FOR GOOD COORDINATION.

3. A DROP COORDINATOR IS NEEDED TO CONTROL AND DIRECT AIR TANKER ACTIVITY. HE SHOULD BE A STRONG SUPERVISOR AND AN EXPERIENCED FIRE CONTROL TECHNICIAN AND SHOULD HAVE SUFFICIENT RANK IN THE ADMINISTRATIVE HEIRARCHY TO COMMAND RESPECT OF BOTH GROUND AND AIR FORCES.

4. THERE MUST BE A CLOSE WORKING RELATIONSHIP BETWEEN THE FIRE BOSS AND THE DROP COORDINATOR ON A FIRE AT ALL TIMES.

5. IF THERE ARE A SERIES OF FIRE SETS, THE AIR TANKERS CAN PERHAPS BE MOST PROFITABLY USED ON THE SMALLER, MOST ISOLATED FIRES.

6. CRITIQUES BETWEEN GROUND AND AIR PERSONNEL ARE HIGHLY DESIRABLE FOLLOWING EACH FIRE ACTION TO OBTAIN MAXIMUM COORDINATION OF FIRE CONTROL EFFORT.

TACTICAL USE OF AIR TANKERS ON FIRES:

1. AIR TANKERS SHOULD BE USED THE SAME AS ANY OTHER FIRE TOOL, WITH ESSENTIALLY THE SAME STRATEGY AND TACTICS.

2. RETARDANT LINES SHOULD BE LOCATED IN MUCH THE SAME PLACES AS ANY OTHER TYPE OF CONSTRUCTED LINE: AT THE HEAD OF THE FIRE IF ITS BEHAVIOR INDICATES SUCH ACTION IS LIKELY TO BE SUCCESSFUL, ON THE FLANKS IF HEAD ACTION CANNOT BE SUCCESSFUL, IN AN INDIRECT LOCATION IF A DIRECT LINE IS LIKELY TO BE OUTFLANKED, IN THE LIGHTER FUELS, TAKING ADVANTAGE OF NATURAL BARRIERS, ETC.

3. AIR TANKERS SHOULD ATTEMPT TO ENTIRELY CONTAIN A SMALL FIRE, IF THEY CAN. IF THEY CANNOT ENTIRELY SURROUND THE FIRE WITH THEIR FIRST SERIES OF DROPS AND NO GROUND FORCES ARE AVAILABLE FOR FOLLOW-UP, THEY MAY BE MOST SUCCESSFUL IN FLANKING ACTION, EVEN ON SMALL FIRES.

4. ON LARGE FIRES AIR TANKERS ARE MOST EFFECTIVELY USED IN HOT-SPOTTING, ON SPOT FIRES, IN FLANKING ACTION, AND IN PRETREATMENT WORK.

5. ON FAST MOVING FIRES AIR TANKERS ARE MORE OFTEN SUCCESSFUL ON FLANKING ACTION TIED TO AN ESTABLISHED FIREBREAK.

6. HOT FIRES RUNNING SWIFTLY UP A STEEP SLOPE IN HEAVY FUELS CAN BE ATTACKED MOST SUCCESSFULLY BY AIR TANKERS BY PRETREATING RIDGES OR BENCHES WHERE FIRE SPREAD WILL SLOW OR LIGHTER FUELS WHICH ARE MORE EASILY HELD BY A GIVEN DROP OF RETARDANT. FLANKING ACTION IS ALSO USUALLY SUCCESSFUL IN THESE CASES.

7. ON HIGH INTENSITY FIRES LARGER AIR TANKER TYPES OR THE OVERLAPPING OF DROPS BY SMALLER TYPES MAY BE DESIRABLE.

8. A SUSTAINED AIR TANKER OPERATION REQUIRES PLANNING FOR RELIEF OF PILOTS, OCCASIONAL MAINTENANCE OF AIRCRAFT, ADDITIONAL SUPPLIES OF GASOLINE AND OIL FOR AIRCRAFT, ADDITIONAL RETARDANT SUPPLIES, POSSIBLE RELIEF OF AIRPORT PERSONNEL, ETC.

9. AIR TANKERS SHOULD RARELY BE USED IN MOP-UP ACTION.

DROP TECHNIQUES:

1. EACH PILOT SHOULD KNOW THE HEIGHT AND SPEED WHICH WILL PROVIDE THE OPTIMUM DROP PATTERN FROM HIS TANKER.

2. DROPS SHOULD NOT BE MADE FROM ALTITUDES BELOW 50 FEET BECAUSE OF THE DANGER TO GROUND PERSONNEL, POSSIBLE DAMAGE TO EQUIPMENT, THE POSSIBILITY OF THE PROP WASH FANNING THE FIRE INTO GREATER ACTIVITY, AND THE WASTE OF RETARDANT.

3. PILOTS SHOULD BE TRAINED TO JUDGE DROP HEIGHTS.

4. DROPS SHOULD NOT BE MADE AT RIGHT ANGLES TO THE FIRELINE IF THEY CAN BE AVOIDED.

5. FOR SAFETY OF OPERATION, AIR TANKERS SHOULD DROP INTO THE WIND WHEN WINDS ARE ABOVE 20 MILES PER HOUR.

SAFETY:

1. STEEP TOPOGRAPHY, DENSE SMOKE, HIGH TIMBER AND SNAGS, SHIFTING AND HIGH VELOCITY WINDS, AND TURBULENT AIR ARE ALL FLYING HAZARDS AND MAY RESTRICT OR EXCLUDE AIR TANKER USE.

2. THUNDERCLOUDS INDICATE THE PRESENCE OF DANGEROUS DOWN DRAFTS.

3. HIGH TELEPHONE AND POWER LINES ON A FIRE SHOULD BE REPORTED TO INCOMING AIR TANKERS.

4. AIRPORTS HAVING HIGH MILITARY OR CIVILIAN TRAFFIC SHOULD BE INFORMED WHENEVER AIR TANKER ACTION IS TO TAKE PLACE ON A FIRE NEAR TO THEM.

5. DROPS MADE FROM AN ALTITUDE BELOW 50 FEET SHOULD BE AVOIDED BECAUSE OF THE POTENTIAL DANGER TO GROUND PERSONNEL.

6. AIR TRAFFIC ON A FIRE MUST BE CONTROLLED AT ALL TIMES, ONE PERSON IN COMMAND OF THE OPERATION.

7. DISAGREEMENTS AMONG AIR PERSONNEL AS TO TACTICS MUST BE AVOIDED DURING FIRE ACTION; THEY CAN BE DISCUSSED AT A LATER CRITIQUE.

RETARDANTS:

1. CARE SHOULD BE TAKEN TO BE SURE THAT ALL RETARDANTS ARE PROPERLY MIXED.

2. WITH OUR PRESENT KNOWLEDGE, VISCOSITY APPEARS TO BE A VERY DESIRABLE CHARACTERISTIC IN ANY RETARDANT SLURRY. IT IS ESPECIALLY IMPORTANT IN A GOOD BENTONITE SLURRY.

3. THE DROP CHARACTERISTICS OF WELL-MIXED BORATE AND BENTONITE ARE ABOUT THE SAME UNDER ALL CONDITIONS.

4. INCREASING THE HEIGHT AND SPEED OF AN AIR TANKER WILL INCREASE THE DRIFT OF ANY RETARDANT DROPPED.

5. BENTONITE AND BORATE APPEAR TO BE EQUALLY EFFECTIVE IN RETARDING FIRE SPREAD WHEN DROPPED RELATIVELY NEAR TO THE FIRELINE. THE LOWER COST OF BENTONITE SHOULD BE CONSIDERED IN SELECTING THE RETARDANT TO BE USED.

6. IF THE FIRELINE PROBABLY WILL NOT REACH THE DROP LINE WITHIN ONE AND A HALF TO TWO HOURS, THEN BORATE SHOULD BE USED RATHER THAN BENTONITE.

FUTURE STUDIES TO IMPROVE THE USE OF AIR TANKERS AND FIRE RETARDANTS INCLUDE CONTINUED EVALUATION OF AIR TANKER USE ON FOREST FIRES; THE STUDY OF ADDITIONAL FIRE RETARDANTS SUCH AS A VERMICULITE-BENTONITE MIXTURE, AMMONIUM PHOSPHATE, VISCOUS WATER WITH AND WITHOUT ADDED CHEMICALS, AND BENTONITE FOAM; TESTS TO DETERMINE THE IMPACT FORCES OF RETARDANT DROPS ON GROUND PERSONNEL; STUDIES OF DIFFERENT RETARDANT MIXERS; THE DETERMINATION OF RETARDANT CHARACTERISTICS IMPORTANT FOR PENETRATION OF DENSE VEGETATIVE CANOPIES; AND THE STUDY OF RETARDANT CONCENTRATIONS NEEDED FOR DIFFERENT FUEL TYPES UNDER DIFFERENT BURNING CONDITIONS.

DESCRIPTION OF PROJECT

OBJECTIVES

1958 AIR TANKER ACTIVITIES PROVIDED VALUABLE INFORMATION IN CERTAIN SPECIFIC AREAS (REINECKER, 1960), BUT THERE APPEARED TO BE TOO MANY GAPS IN THE AVAILABLE DATA TO PERMIT AIR TANKERS TO BE PLACED IN PROPER PERSPECTIVE WITH OTHER FIREFIGHTING FORCES. THESE ADDITIONAL NEEDS WERE REFLECTED IN THE FOLLOWING OBJECTIVES FOR THE 1959 PROGRAM:

1) EXAMINE THE EFFECTIVENESS OF SEVERAL AIR TANKER TYPES IN RELATION TO VARIOUS FIRE SITUATIONS.

2) Establish guidelines for developing local dispatch and tactical use criteria for initial attack and follow-up fires.

3) Study abilities of pilots and aircraft to perform effectively in dropping retardant chemicals on forest fires.

4) Study methods of integrating air and ground forces for initial attack operations.

5) Study economics of air tanker use.

Standards

In order to accomplish these objectives it was imperative that variable factors be stabilized or minimized as much as possible. The following procedures were initiated or strengthened after 1958 experiences:

1) Equipment standards

In 1958 there was considerable variability noted in tank and gate designs. It was found that certain tank designs with protruding lips, flanges or other areas of entrapment caused the chemical to break up too quickly or to string out beyond the target. Only that equipment which would produce a clean, quickly expelled drop was acceptable. Generally speaking, this meant that gates were as large as the tank bottom would permit with no obstructions to the flow of the retardant.

2) Retardant standards

With the use of bentonite as a fire retarding chemical, the need to maintain close control over mixing techniques became increasingly apparent. Thin mixes of either borate or bentonite can produce poor patterns and may be ineffective in retarding fire spread. Bentonite, being most critical in this respect and being influenced by minerals in the water, made it necessary to have close inspection of each mixing operation.

3) Central inspection and direction system

To assure that adequate facilities were established and maintained; that operational problems were not influencing the evaluation; that personnel were properly performing their assigned duties; and that air and ground operations were coordinated, required that an administrative position from the district office be assigned the responsibility of periodically inspecting the forces assigned to the program. Since the evaluation forces were located in more than one ranger administrative unit, it was important to maintain uniformity.

4) Pilot proficiency standards

1958 experience indicated that the variation in pilot abilities was sometimes greater than the variation between aircraft types. This probably posed the most serious obstacle to good objective evaluation. New air tanker pilots, even those with many hours of agricultural work, are of limited value for evaluation purposes for a considerable time. Pilots with no agricultural flying may require 100 or more drops on fires before becoming proficient enough to be dependable. Of the pilots used in the

1959 experimental program, only one had no previous experience and the majority had worked in the 1958 experimental program.

Mixed groups of green and experienced pilots can create serious competition problems. The experienced man may try to demonstrate his abilities, and the green man may exceed his experience by trying to equal the other's performance. Mixed types of aircraft can likewise result in competition to prove one type better than the other. Such competition not only affects evaluation but creates a serious safety problem.

5) System for recording effectiveness of drops

It was noted in 1958 that any one drop observed by ground personnel could be reported as effective, partially effective, or ineffective, depending on how each individual saw it from his location. The complete target was not always in view of ground forces due to intervening topography or heavy foliage. It was found that movies taken from the air, using the proper techniques, could provide a good method of recording actions for later subjective evaluation. Photographers for 1959 were given instructions by viewing sample photography showing both good and bad techniques. Nevertheless, some of the past mistakes were repeated until each photographer had gained experience and had reviewed some of his own movies. Best results were realized when shots were taken of the target before a drop, of the drops themselves, and of the fire area after the drop with sufficient footage to study effects.

Reports from ground forces and aerial observers were made on each air tanker operation in 1959 in a manner similar to 1958 (Reinecker, 1960). These provided the data for the analyses and summaries shown elsewhere in this report.

Program

In order to reduce the variability of different pilots and different aircraft being used under various fire situations throughout the State, at least half of the experiment was developed around a team of four air tankers. The team consisting of three N3N's (200 gallons maximum) and one Twin Beech (300 gallons maximum), operated six weeks in the Division's Central Sierra District (District III), then moved to the North Coast District (District I) for six weeks, and finally to the Southern California District (District VI) for the remainder of the fire season (figs. 1 and 2). Two photographers were assigned to the team and moved with them. Two "dropcos" (drop coordinators) and Cessna 180's or 182's were assigned by the district in which the team operated.

Fig. 1. N3N air tanker, 200 gallons maximum capacity, used in initial attack experiment.

Fig. 2. Twin Beech air tanker, 300 gallons maximum capacity, used in initial attack experiment.

In District III the aircraft were distributed as follows: Loma Rica near Nevada City (later moved to Auburn), three N3N's and one dropco; Columbia, one Twin Beech and one dropco. An additional TBM (600 gallons maximum) at Columbia was part of the experiment, but this ship remained at Columbia for the entire season.

In District I the aircraft were located as follows: Hoberg's, Lake County, two N3N's and one dropco; Ukiah, one N3N, one Twin Beech, and one dropco. No additional air tankers were provided for the periods before arrival or after departure of the team.

In District VI the entire team and one dropco were located at Ryan Field, Riverside County. In addition, one TBM, one F7F (800 gallons maximum), and one dropco were located at Ramona for the entire fire season (figs. 3 and 4). These were also included in the experiment.

Fig. 3. F7F air tanker, 800 gallons maximum capacity, stationed at Ramona Airport in 1959.

Fig. 4. TBM air tanker, 600 gallons maximum capacity. This type of aircraft was stationed both at Columbia and Ramona Airports in 1959 for the initial attack experiment.

Initial attack definition

For the purposes of the 1959 experiment, definition of "initial attack" was confined to that action which occurred as follows:

1) An air tanker was dispatched before any other unit.

2) An air tanker was able to take action on a going fire at least within 15 minutes of the arrival of the first ground crew.

Criteria for standby and dispatching procedure

Air tankers were placed on standby when the brush burning index (California Fire Danger Rating System) was predicted for 9 or above. They were also held on standby with the brush burning index below 9 when heavy fire activity the previous day had involved a large percent of the normal suppression forces, or when a large number of fire starts from lightning or incendiarism had committed most of the other initial attack forces.

Dispatch criteria were aimed at those fires having the greatest potential of becoming C, D, or E size fires (within the limited funds of the experimental program). It was recommended that maps be prepared for each operating area eliminating those areas known to consist of dense residential developments, power and telephone line hazards, and of low resistance to control. It was also recommended that areas of high value, high resistance to control, long travel times for ground crews, and areas which were within 20 minutes travel time from the established airports be delineated on dispatcher's maps. This was done to varying degrees, however, and dispatching was influenced greatly by low fire incidence and, consequently, limited opportunities for use in some districts in 1959.

The time for standby to begin on any given day was varied from 0800 to 1200 hours, depending on the predicted hazard. The aircraft were checked out, warmed up, and the air tankers loaded with retardants prior to the standby time. When a fire was reported on which air tankers were to be used, they were dispatched in the same manner as other fire control forces. Dispatch information included location by section, township, and range, nearest town or landmark, distance, heading in degrees from airport, and elevation of the fire. Dropco's responded with the air tankers and maintained radio contact for coordination with ground forces.

Operating Procedures

When air tankers arrived at a fire prior to ground forces and the DROPCO, they took independent action in accordance with prior fire control training (see section on Training). Otherwise the DROPCO assumed the responsibility for selecting targets or coordinating drops with the requirements of ground forces. Once the ground forces arrived, the fire boss "called the shots" for air tanker activity through the DROPCO. It was not unusual, however, because of his overall view of the fire, for the DROPCO to suggest to the fire boss the appropriate action.

Since DROPCO's were not normally pilots nor familiar with the limitations and performance characteristics of air tankers, they did not attempt to lead the air tankers into the target nor to tell the pilots how to make their drops. On the initial action the DROPCO might make a low level pass over the fire area and would then inform pilots of hazards, air turbulence, or other pertinent information. Otherwise, the DROPCO maintained an orbit at 1,000 feet above the area and coordinated the orbiting, approach and departure of the air tankers. The extent of direction from the DROPCO with regard to the drop itself was confined to identifying the target and indicating when the drop was to be made. The manner in which the drop was made was left to the pilot; final decision on whether the drop could be safely made was also left to the pilot.

PROJECT MANAGEMENT

Although aircraft, pilots, and personnel were assigned to specific bases and were dispatched by a ranger unit dispatcher, the striking range of the air tankers was not confined to any single administrative unit. Three or more ranger units were within one-half hour flight time from each base of operations.

In order to have continuity and consistency of use it was necessary to establish a direct administrative contact from the district headquarters to the project personnel. This responsibility was assigned in each case to the district fire control ranger. This procedure posed problems of coordination at times since normal administrative channels through the ranger units were being by-passed. Every effort was made to keep local fire control personnel informed, however.

Likewise, since the project was a statewide experiment, close liaison was necessary from Sacramento headquarters fire control office. The ranger unit in which an airport was located was responsible for providing equipment and personnel to operate the base and coordinating the day to day business within the guidelines established by Sacramento and district headquarters. The 1959 project differed from 1958 in that the district fire control ranger acted as project leader for the forces in his district. A separate project leader was used in 1958.

One DROPCO was located at each base. This position was filled with one exception by forest firefighter foremen in 1959. Foremen, assistant rangers, and associate rangers were used in 1958. The DROPCO was in charge of the base and was responsible for supervising support activities. He inspected daily the mixing and storage facilities and made checks to determine that pilots and aircraft were in compliance with contract terms. When airborne, he was responsible for coordinating air tanker activity with the requirements of ground forces.

One forest firefighter was assigned to each base to act as timekeeper, to assist with loading operations, and to operate base communication systems. Crews consisting of three firefighters, one driver, and the DROPCO were permanently stationed at two

OF THE LARGER BASES (RYAN AND RAMONA). MIXING WAS USUALLY DONE WITH CONSERVATION CAMP OR CALIFORNIA DIVISION OF FORESTRY CREWS.

FACILITIES

AIRPORT FACILITIES VARIED FROM GOOD TO BAD, WITH MUCH TO BE DESIRED AT MOST LOCATIONS IN THE WAY OF BOTH EQUIPMENT AND ARRANGEMENT (FIG. 5). MUCH OF THE INADEQUACY WAS DUE TO THE SHORT NOTICE WITH WHICH THE EXPERIMENT WAS LAUNCHED. FUNDS HAD TO BE TAKEN FROM OTHER BUDGETED PROGRAMS, EQUIPMENT HAD TO BE OBTAINED WHEREVER IT MIGHT BE IMMEDIATELY AVAILABLE (MOST PUMPS AND STORAGE TANKS WERE OBTAINED FROM FEDERAL SURPLUS SUPPLIES), PERSONNEL TO MAN THE PROGRAM HAD TO BE TAKEN FROM THE REGULAR FIRE CONTROL FORCES AND THEREFORE WERE, OF NECESSITY, LIMITED BOTH IN NUMBER AND IN TRAINING IN AIR OPERATION PROCEDURES. ADEQUATE PERSONNEL AND FACILITIES, PROPERLY ARRANGED, CAN PROVIDE THE KEY TO DECREASING THE "DOWN-TIME" OF AIRCRAFT ON A SUSTAINED FIRE CONTROL OPERATION. THE FOLLOWING ARE RECOMMENDATIONS FOR MINIMUM FACILITIES FOR PERMANENT AIR TANKER BASES

FIG. 5. MIXING FACILITIES WERE INADEQUATE AT MANY AIR TANKER BASES IN 1959.

STORAGE

TANKS FOR BOTH BENTONITE AND BORATE SHOULD BE PROVIDED WITH A TOTAL CAPACITY OF NOT LESS THAN 10,000 GALLONS WHERE SMALL AIR TANKERS ARE USED AND 30,000 GALLONS WHERE LARGER AIR TANKERS ARE USED. IN ANY EVENT, THERE SHOULD BE A SUFFICIENT BACK-LOG OF CHEMICAL FOR A SUSTAINED OPERATION OF AT LEAST FOUR HOURS WITHOUT ADDITIONAL MIXING OF RETARDANT.

LOADING AND MIXING FACILITIES

A TRANSFER PUMP CAPABLE OF DELIVERING 500 GALLONS PER MINUTE IS DESIRABLE AT ALL LOCATIONS WITH THE POSSIBLE EXCEPTION OF THOSE BASES WHERE ONLY SMALL AIRCRAFT CAN BE USED. EXPERIENCE HAS SHOWN THAT A MAJOR PORTION OF THE DOWN-TIME IS CONSUMED BY LOADING. TWO $2\frac{1}{2}$" LOADING HOSES SHOULD BE PROVIDED AND ARRANGED SO THAT TWO AIRCRAFT MAY BE LOADED SIMULTANEOUSLY OR SO THAT BOTH HOSES CAN BE USED TO FILL ONE LARGE AIR-CRAFT. TWO ALTERNATE SMALLER TRANSFER PUMPS SHOULD BE ON HAND TO USE IN EVENT OF FAILURE OF THE PRIMARY PUMP. ONE PRESSURE PUMP CAPABLE OF PRODUCING 100 GPM WILL BE NEEDED WHEN INJECTOR TYPE MIXERS ARE USED TO MIX THE CHEMICAL.

THE MIXING AND LOADING AREAS SHOULD BE LOCATED SEPARATELY SO THAT BOTH OPERATIONS MAY BE CONDUCTED SIMULTANEOUSLY. ADEQUATE DRAINAGE SHOULD BE PROVIDED AT BOTH AREAS SO THAT RETARDANT SPILLAGE MAY BE WASHED AWAY WITHOUT AFFECTING OTHER AIRPORT FACILI-TIES. WATER UNDER PRESSURE SHOULD BE AVAILABLE FOR WASHING AIRCRAFT. LOADING AREAS SHOULD BE PAVED OR COATED TO ELIMINATE THE DUST PROBLEM RESULTING FROM PROPELLER BLAST AND TO FACILITATE REMOVAL OF SPILLED RETARDANTS.

A BATCH TYPE MIXER FOR BENTONITE WILL UNDOUBTEDLY PROVE TO BE THE MOST EFFECTIVE AND RELIABLE FOR LARGE, PERMANENT BASES. A PORTABLE INJECTOR TYPE MIXER SHOULD BE ON HAND AS AN ALTERNATE AT PERMANENT BASES AND WILL BE ADEQUATE FOR MOST TEMPORARY BASES.

A WAREHOUSE OF SOME SORT IS RECOMMENDED FOR DRY CHEMICAL STORAGE. SUFFICIENT SPACE SHOULD BE PROVIDED FOR A SEASON'S SUPPLY OF MATERIAL.

Fueling facilities

Storage of aircraft fuel should be adjacent to but should in no way interfere with the chemical storage and loading area. Consideration should be given to providing high test fuel for certain aircraft types.

Briefing and dispatching room

Experience has shown that a room, small building or trailer with facilities for desk work and lounging is highly desirable. A dispatch map should be provided with a compass rose around the airport location oriented so that magnetic directions can be provided to the pilots.

Lounging and recreation facilities

There are many hours and days when air tankers on initial attack standby will not be used because of no fire occurrence. Lounging and recreation facilities should be provided for pilots during these periods. Waiting for fire action can become exceedingly boring if no mental and physical outlets are available.

Airport standards

Only those airports should be used which have been approved for the type of aircraft being utilized. Through a cooperative program with the U. S. Forest Service, all available fields in California have been categorized into classes. Many have been ruled out because of inadequacies, location, volume of air traffic, etc. Because of the additional hazards which an air tanker operation places on any airport, it is essential that every effort be made to conduct the operation with a reasonable margin of safety. Close cooperation with airport management should be initiated so that there will be as little interference as possible with regular activity. Pilots must be cautioned to observe all normal procedures concerned with approach, landing, taxi, and take-off.

CONTRACTS

All aircraft used in the initial attack experiment were placed under formal contracts after competitive bids were solicited for each area of operation. Bids were based on a rate per hour by aircraft type. The specifications stipulated minimum requirements for pilots and aircraft (by type), conditions of use and operating procedures. Following is a summary of the specifications:

Aircraft

1. N3N

   Payload capacity of not less than 180 gallons of fire retardant (at 9.0 pounds per gallon) at a density altitude of 6,300 feet (3,000 foot pressure altitudes at 100°F). Total tank capacity 200 gallons. Tank discharge opening not less than 450 square inches (all N3N's supplied had 500 square inch openings). Engine horsepower not less than 600. Equipped with an electric starter.

2. Twin Beech

Payload capacity of not less than 300 gallons with total capacity of 380 gallons divided between two tanks. Each tank equipped with a separate gate and capable of being opened independently with no less than 600 square inches in each opening. Combined horsepower of both engines not less than 900.

3. TBM

Payload capacity of not less than 500 gallons and total tank capacity of 600 gallons divided into two equal compartments with independently operated gates. Discharge openings not less than 1,000 square inches for each compartment. Engine horsepower not less than 1,900.

4. F7F

Payload capacity not less than 750 gallons and total tank capacity of 800 gallons divided into two compartments with independently operated gates. Discharge openings not less than 1,400 square inches for each compartment. Combined horsepower for both engines not less than 4,200.

Pilots

Each pilot was required to have a minimum experience of not less than 1,500 hours of flight time, of which not less than 500 hours was in agricultural flying at low elevations, or 200 hours of timber spraying, cargo dropping, air tanker application, seeding, baiting, fish planting, or similar low level mountain flying experience.

Payment

A minimum payment was guaranteed for each aircraft. The amount varied depending on the type of ship and the length of time involved but generally amounted to slightly less than one hour (at the bid rate) per day of the contract period. All flight time was charged against the minimum guarantee. Two methods of applying the minimum guarantee were tried. One method provided the guarantee at the end of the contract period while the other prorated the guarantee by weekly periods. It was found that the former method provided the greatest flexibility. The latter method does not allow for "peaking" aircraft use with fire occurrence (except during each weekly period) to take advantage of the guarantee for actual flight time.

General

To be competitive, specifications were written around aircraft and gate designs which were generally available. There was little opportunity to develop new tank designs or gate release mechanisms except as was done voluntarily by the individual operator.

Insurance coverage for aircraft and pilots engaged in this type of work is extremely high and of necessity must be reflected in the rental rate. A serious question arose in 1959 as to the availability of compensation insurance for the contractor's pilot. There is no assurance that compensation insurance will continue to be available in future years.

Although the Division's contracts specified that all necessary maintenance

WOULD BE PERFORMED AS STIPULATED BY F.A.A. REQUIREMENTS, THE LACK OF TECHNICALLY TRAINED PERSONNEL TO PERIODICALLY INSPECT THE AIRCRAFT MADE IT IMPOSSIBLE TO ASSURE COMPLIANCE. EVEN TECHNICALLY TRAINED PERSONNEL CANNOT ALWAYS DETERMINE WHETHER CERTAIN ENGINE MAINTENANCE HAS BEEN PERFORMED. HERE THE DIVISION HAD TO RELY ON THE INTEGRITY OF THE OPERATOR. AIRCRAFT USED FOR THIS PURPOSE NEEDS A LEVEL OF INSPECTION AND MAINTENANCE EQUAL TO THAT OF COMMERCIAL AIRLINE SERVICE.

A RATHER LARGE INVESTMENT TO AN INDIVIDUAL CONTRACTOR IS REPRESENTED IN EACH ONE OF THESE AIRCRAFT. THE MAJORITY ARE SPECIALLY DESIGNED FOR FIRE CONTROL WORK AND HAVE NO OTHER USE. A LARGE NUMBER OF NEW OPERATORS ARE CONTINUING TO ENTER THIS FIELD OF ACTIVITY BECAUSE OF THE EXTENSIVE USE OF THE EXISTING SHIPS DURING THE PAST YEARS. CERTAINLY CONTRACTS WITH EITHER THE STATE OR THE FOREST SERVICE ARE LIMITED TO ONLY A SMALL PORTION OF THE NUMBER OF AIR TANKERS AVAILABLE. THE REMAINDER RELY ON THE OCCURRENCE OF FIRES IN AREAS WHERE NO CONTRACT EXISTS, THE DEVELOPMENT OF LARGE FIRES NEEDING MANY AIRCRAFT OR THE OCCURRENCE OF MORE FIRES AT ONE TIME THAN THE CONTRACT AIRCRAFT CAN HANDLE.

UNDER THE CONTRACT SYSTEM, EACH YEAR THE DIVISION MUST NEGOTIATE FOR NEW CONTRACTS AND HENCE THERE IS A POSSIBILITY OF ACQUIRING A COMPLETELY NEW GROUP OF PILOTS AND AIRCRAFT. ALTHOUGH THE DIVISION SPECIFIES A CONSIDERABLE BACKGROUND OF FLYING TIME OF WHICH A CERTAIN PORTION MUST BE AT LOW LEVEL, FIRE CONTROL WORK IS AN ART IN ITSELF. THERE IS NO MEANS BY WHICH THE DIVISION CAN RETAIN ITS INVESTMENT OF TRAINING AND EXPERIENCE WITHOUT RESTRICTING SPECIFICATIONS TO THE POINT WHERE NO COMPETITION WOULD EXIST.

TRAINING

AS IN ALL OTHER ASPECTS OF FIRE CONTROL OPERATIONS, COMPLETE TRAINING OF ALL PERSONNEL INVOLVED IN THE AIR TANKER PROGRAM IS ESSENTIAL FOR EFFECTIVE, ECONOMIC, AND SAFE OPERATIONS. ALL PERSONNEL SHOULD RECEIVE BASIC TRAINING IN AT LEAST THE FOLLOWING SUBJECTS:

1. OBJECTIVES OF THE PROGRAM
2. GENERAL ORGANIZATION AND RESPONSIBILITIES OF PERSONNEL CONCERNED WITH THE TOTAL PROGRAM.
3. AIR TANKER ORGANIZATION: AIR BASE FACILITIES, INITIAL ATTACK, SUSTAINED OPERATION.
4. DISPATCHING PROCEDURES.
5. FORMS AND RECORDS.
6. COMMUNICATIONS
7. SAFETY IN ALL PHASES OF THE OPERATION.

IN ADDITION SPECIFIC GROUPS OF PERSONNEL SHOULD RECEIVE OTHER SPECIALIZED TRAINING, AS FOLLOWS:

PILOTS

PILOTS MUST BE TRAINED MOST PARTICULARLY IN SAFE AND EFFECTIVE OPERATIONS WHILE IN ACTION ON OR NEAR A FOREST FIRE. KNOWLEDGE OF THEIR WORKING RELATIONSHIPS WITH OTHER FIRE CONTROL PERSONNEL IS ALSO NECESSARY.

TRAINING SHOULD INCLUDE AT LEAST ONE FORMAL SESSION NEAR THE BEGINNING OF EACH FIRE SEASON TO ACQUAINT, OR REACQUAINT, PILOTS WITH ALL PHASES OF FIRE CONTROL ORGANIZATION AND TACTICS. LESS FORMAL SESSIONS SHOULD BE CONDUCTED ON A CONTINUING

BASIS THROUGHOUT THE FIRE SEASON TO REVIEW IMPORTANT POINTS AND TO GRADUALLY INCREASE THE LEVEL OF KNOWLEDGE OF THE PILOTS.

CRITIQUES SHOULD BE HELD FOLLOWING EVERY FIRE ACTION, IF AT ALL POSSIBLE, THIS CRITIQUE SHOULD INCLUDE THE PILOTS AND DROP COORDINATORS FROM ALL AIR TANKER BASES INVOLVED IN THE FIRE ACTION AND PERSONNEL WHO WERE ENGAGED IN FIGHTING THE FIRE FROM THE GROUND. SUCH CRITIQUES ARE NECESSARY AND HELPFUL IN SMOOTHING OUT COORDINATION BETWEEN GROUND AND AIR FORCES AND IN CORRECTING MISTAKES INADVERTENTLY MADE EITHER BY THE AIR TANKER PILOTS OR THE GROUND FORCES BECAUSE OF A LACK OF KNOWLEDGE, TRAINING, OR UNDERSTANDING.

THE FORMAL TRAINING SESSION NEAR THE BEGINNING OF THE FIRE SEASON MAY VARY IN CONTENT ACCORDING TO THE EXPERIENCE OF THE INDIVIDUAL PILOTS BUT PROBABLY SHOULD INCLUDE AT LEAST THE FOLLOWING ITEMS IN ADDITION TO THE BASIC TRAINING:

1. FIRE BEHAVIOR PRINCIPLES.
2. AGREEMENTS.
3. AIRCRAFT AND PILOT STANDARDS.
4. FLIGHT AND DROP TECHNIQUES, INCLUDING KNOWLEDGE OF OPTIMUM DROP PATTERNS AND ESTIMATION OF HEIGHT ABOVE THE VEGETATION.
5. AERIAL TACTICS ON FIRES.
6. COORDINATION WITH GROUND FORCES, WITH OTHER AIRCRAFT AND WITH OTHER FIREFIGHTING AGENCIES.

DROP COORDINATORS

SINCE THE DROP COORDINATOR IS PRESUMED TO BE AN EXPERIENCED FIRE CONTROL MAN, HIS TRAINING WILL BE PRINCIPALLY ALONG THE LINES OF SUPERVISING THE AIR TANKER UNIT AT THE AIRPORT AND IN ACTION ON FOREST FIRES AND OF COORDINATING THE AIR FORCES WITH THE GROUND FORCES. BASIC TRAINING SHOULD BE SUPPLEMENTED BY ALL SUBJECTS INCLUDED IN PILOT TRAINING AND ALSO THE FOLLOWING ITEMS:

1. DIRECTION OF PILOTS ON THE GROUND AND IN THE AIR.
2. FISCAL ASPECTS OF THE PROGRAM.
3. KNOWLEDGE OF FIRE RETARDANTS.
4. PRINCIPLES OF FLIGHT AND LIMITATIONS OF AIRCRAFT.
5. FLIGHT WEATHER.

AIRPORT PERSONNEL

FACILITATING AND SERVICING PERSONNEL WILL NORMALLY BE AVAILABLE AT THE AIR BASE TO MIX AND LOAD FIRE RETARDANT SLURRIES, TO MAINTAIN FACILITIES, AND OCCASIONALLY TO DISPATCH AND TO MAINTAIN OFFICE RECORDS. THESE PEOPLE SHOULD BE TRAINED IN BASIC SUBJECTS AND THE FOLLOWING ADDITIONAL SUBJECTS:

1. WORKING KNOWLEDGE OF DIFFERENT TYPES OF RETARDANTS.
2. MIXING, STORING, AND LOADING OPERATIONS.
3. CHARACTERISTICS OF AIRCRAFT WHILE ON THE GROUND.
4. SERVICING OF AIRCRAFT WITH FUEL AND OIL.

FIRE MANAGERS

IT IS ESPECIALLY IMPORTANT FOR FIRE MANAGERS TO BE THOROUGHLY ACQUAINTED WITH ALL ASPECTS OF THE AIR TANKER PROGRAM AND TO KNOW HOW, WHEN, AND WHERE TO INTEGRATE THE AIR TANKER WITH ALL OTHER FIRE TOOLS AVAILABLE FOR A SPECIFIC FIRE. HE IS RESPONSIBLE MORE THAN ANY OTHER ONE PERSON FOR DECIDING WHEN AIR TANKERS SHOULD BE REQUESTED FOR USE ON A GOING FOREST FIRE, WHERE AND HOW THEY CAN MOST EFFECTIVELY HELP SUPPRESS THE FIRE, AND WHEN THEIR USE SHOULD BE TERMINATED, EITHER FOR REASONS

OF ECONOMY OR BECAUSE THEY HAVE PERFORMED ALL THE WORK FOR WHICH THEY ARE BETTER SUITED THAN ANY OTHER FIRE TOOL.

THESE SAME PRINCIPLES APPLY, OF COURSE, TO THE USE OF ANY OTHER TYPE OF FIRE TOOL, AND HEREIN LIES THE SECRET OF EFFICIENT MANAGEMENT OF THE AIR TANKER AS A FIRE TOOL: IT SHOULD BE USED THE SAME AS ANY OTHER TOOL, IN MUCH THE SAME PLACES, IN MUCH THE SAME MANNER, AND WITH MUCH THE SAME STRATEGY AND TACTICS. THE AIR TANKER IS NOT A SUPER-TOOL BUT IS CAPABLE OF PERFORMING CERTAIN TASKS IN A SUPERIOR AND ECONOMIC MANNER. IT IS THEREFORE ESSENTIAL THAT ALL FIRE MANAGERS WHO ARE POTENTIAL USERS OF AIR TANKERS BE THOROUGHLY ACQUAINTED AND TRAINED IN THE AIR ATTACK PROGRAM. A TRAINING PROGRAM FOR FIRE MANAGERS SHOULD INCLUDE AT LEAST THE FOLLOWING SUBJECTS IN ADDITION TO BASIC TRAINING:

1. FLIGHT AND DROP CHARACTERISTICS OF AIR TANKERS.
2. CAPACITIES OF DIFFERENT AIR TANKERS.
3. AERIAL TACTICS ON FIRES.
4. COORDINATION OF GROUND AND AIR FORCES; MAINTENANCE OF CONTACT WITH DROP COORDINATOR OR A LEAD PILOT.
5. NECESSITY OF COMMUNICATING SPECIAL GROUND HAZARDS TO AIR FORCES.
6. ALERTING GROUND PERSONNEL TO USE OF AIR TANKERS ON THE FIRE.
7. CHARACTERISTICS OF FIRE RETARDANTS AND THEIR EFFECT ON FIRE BEHAVIOR.
8. FISCAL ASPECTS OF THE PROGRAM.

FIRE CREWS

FIRE CREWS MUST BE TRAINED PRINCIPALLY IN SAFETY ASPECTS AND IN FOLLOW-UP ACTION AFTER A DROP HAS BEEN MADE ON A FIRE FROM AN AIR TANKER. SAFETY WILL INCLUDE KNOWING WHAT EVASIVE ACTION TO TAKE WHEN IN THE IMMEDIATE TARGET AREA AND WHAT CARE IS NEEDED WHEN HIKING AND WORKING IN AN AREA WHERE A DROP OF BENTONITE OR VISCOUS WATER HAS ALREADY BEEN MADE (THESE RETARDANTS ARE PARTICULARLY SLIPPERY). CREW LEADERS MAY OFTEN ASSUME THE ROLE OF FIRE MANAGERS AND WILL REQUIRE TRAINING IN THE RESPONSIBILITIES OF THAT PARTICULAR FIRE JOB. TRAINING FOR FIRE CREWS SHOULD INCLUDE BASIC SUBJECTS AND AT LEAST THE FOLLOWING ADDITIONAL ITEMS:

1. FLIGHT AND DROP CHARACTERISTICS OF AIR TANKERS.
2. NECESSITY OF COMMUNICATING SPECIAL GROUND HAZARDS TO AIR FORCES.
3. FOLLOW-UP TACTICS AFTER A DROP HAS BEEN MADE.
4. CHARACTERISTICS OF FIRE RETARDANTS AND THEIR EFFECT ON FIRE BEHAVIOR.

DISPATCHERS

RANGER UNIT DISPATCHERS ARE PRINCIPALLY CONCERNED WITH KNOWING WHEN AIR TANKERS SHOULD BE DISPATCHED ON INITIAL ATTACK. THEIR DECISIONS WILL BE BASED ON CONSIDERABLE PRE-PLANNING, INCLUDING THE POSSIBLE CONSTRUCTION OF AN AIR OPERATIONS MAP WHICH COULD DELINEATE AREAS OF "AUTOMATIC DISPATCH" OF AIR TANKERS UNDER A GIVEN SET OF FIRE CONDITIONS, AREAS OF ALMOST "COMPLETE EXCLUSION" OF AIR TANKER USE EXCEPT UNDER EXTRAORDINARY CONDITIONS, AND A THIRD AREA WHERE AIR TANKERS MAY OR MAY NOT BE DISPATCHED DEPENDING UPON THE COMBINED EFFECTS OF A LARGE NUMBER OF VARIABLES, WHICH ARE DISCUSSED IN MORE DETAIL IN THE NEXT SECTION OF THIS REPORT, "USE OF AIR TANKERS ON FOREST FIRES."

DISPATCHERS WOULD NOT BE PARTICULARLY CONCERNED WITH PRINCIPLES INVOLVED IN DISPATCHING AIR TANKERS ON FOLLOW-UP ACTION SINCE SUCH DISPATCHING WILL BE REQUESTED BY THE FIRE MANAGER BASED UPON HIS OWN EXPERIENCE AND TRAINING. DISPATCHERS SHOULD BE THOROUGHLY TRAINED IN AT LEAST THE FOLLOWING SPECIALIZED SUBJECTS IN ADDITION TO BASIC TRAINING:

1. Capacities and flight characteristics of different air tankers.
2. Principles of pre-planning an air attack organization; integration with existing fire control organization.
3. Principles of dispatching air tankers on initial attack.
4. Strategical and tactical use of air tankers and their relative merits compared to other fire tools.
5. Recognition of special topographic, weather, or improvement hazards which could affect the safety of an air operation.
6. Need of notifying all nearby airports, civil and military, whenever air attack is taking place on a forest fire; all aircraft not directly concerned with action on the fire must be warned to remain away from the fire and be alert to air tankers flying at relatively low altitudes to and from the fire and the base airport.

Air program administrators

Unit administrators who may only rarely be directly concerned with the action and use of air tankers on forest fires will often be directly concerned with the fiscal aspects and with the general planning, directing, and successful conducting of the program. Since they are primarily responsible for the entire program, including training, they should be acquainted in general with all subjects taught to all personnel.

Use of air tankers on forest fires

One of the objectives of the Division's 1959 air tanker initial attack experiment, as has been stated, was to attempt to refine its initial attack dispatching and tactical use guidelines.

How the analysis was made

Data from the reports written by field fire control personnel and from the several thousand feet of 16 mm motion picture film was compiled and analyzed. The overall use of air tankers on any given fire was subjectively judged to be "effective", "ineffective", or "not needed." Because of the many contributing factors, there was no sharp definition of the above terms of effectiveness. The subjective judgments were based on such typical items as whether or not

1) ground crews were making effective action on the fire prior to the arrival of the air tankers,
2) the air tankers permitted ineffective crew action to become effective,
3) the air tankers retarded fire spread, cooled hot spots, or checked spot fires,
4) the final size of the fire was reduced by the use of air tankers,
5) burning conditions were such that ground crews could have readily controlled the fire regardless of air tanker use.

The degree of effectiveness of the air tankers was reduced to several categories in a further attempt to discover clues that would contribute to refinement of use guidelines. Figure 6 shows the categories into which each fire was placed; the number of fires placed in each category by the analysis is noted in parentheses. Categories 3 and 6 are arbitrary by the definition of initial attack used in the analysis and noted on page_____. Air tankers were judged as ineffective on initial attack and placed in categories 5A or 5B, and thence in categories 5C or 3 or 6, if the fire was not controlled by the time of final action of the air tankers on the first day.

Fig. 6. Classification of air tanker effectiveness on forest fires in 1959.

Clues as to why specific air tanker actions fitted into the various categories were obtained by studying the mass of data recorded throughout the experiment. Relative effectiveness or need of air tankers were compared to at least the following factors on all fires:

1. Burning Index
2. Air temperature
3. Relative humidity
4. Wind speed
5. Topography
6. Vegetative type
7. Rate of spread of fire
8. Crew getaway and travel time
9. Air tanker getaway and travel time
10. Distance to fire (crews and air tankers)
11. Time of day
12. Size of fire at time of attack by air tankers
13. Increase in size of fire during air tanker action
14. Retarding of fire by individual drops from tankers
15. Degree of effectiveness of crew action

Judgment of effectiveness based on the above factors was then supplemented by the written comments of fire control personnel and by a study of the motion picture film.

Results of the analysis

Table 1 summarizes the three main groups of effectiveness.

Table 1. Effectiveness of Air Tankers on Division of Forestry Fires, 1959.

	Effective	Ineffective	Not needed	Total
All fires				
Number of fires	102	10	41	153
Percent of total	66	7	27	100
Initial attack only				
Number of fires	53	20	30	103
Percent of total	52	19	29	100

There were nine other fires on which air tankers were used in 1959 but insufficient data did not permit their evaluation

Reasons most evident for effectiveness of air tankers on initial attack were

1. Fast dispatching action.
2. Reaching the fire while it was small (class A or B).
3. Good communications and coordination between ground and air forces.
4. Retarding action by air drops on heads of slower spreading fires and on flanks of faster spreading fires.
5. Favorable topography for good approach pattern of air tankers.

6. Favorable air conditions for good flying.

Reasons most evident for effectiveness on follow-up action were

1. Use of air tankers principally on the flanks (there were twice as many successes with drops made on the flanks of large fires than were made on the heads of such fires).
2. Use of air tankers in hot-spotting and on spot fires to help confine larger fires.
3. Good communications and coordination between ground and air forces.

Reasons most evident for ineffectiveness on initial attack were

1. Reaching a fire after it had spread beyond 10 acres.
2. High intensity, fast spreading fires.
3. Poor communications and poor coordination between ground and air forces.
4. Lack of follow-up by ground forces.
5. Winds over 30 miles per hour, air turbulence, very steep topography or high timber, any one of which could cause high drops and drifting of retardant.

Reasons most evident for ineffectiveness on follow-up action were

1. Poor communications and coordination between ground and air forces.
2. Smoke of large fires obscured targets.
3. Wind, air turbulence, and topography caused some high drops.

The data showed that on those fires on which ground forces were judged to be ineffective in fire control action prior to the arrival of air tankers, the air tankers were also judged to be ineffective in 36 percent of the cases. Therefore it might be said that while the air tankers have failed to solve the large fire problem in all cases, they have helped to some extent. This possibility is supported by the judgments made by fire managers when they estimated that air tanker help was responsible for making 41 percent of the fires smaller than they would have been without such help. These judgments are supported vividly by analysis of air tanker action recorded on motion picture film.

In several instances when air tankers were dispatched as a precaution because burning conditions favored fire spread or a fire was isolated, they were not needed upon arrival because the fire was either under control, being readily controlled, or could easily have been controlled by forces arriving soon. In a few cases the fires were started by lightning from wet storms and were confined to snags or spots. Occasionally air tankers were dispatched to false alarms. If air tankers are to be dispatched quickly on initial attack, there will always be these occasions when they are not needed since this same situation exists in the initial attack dispatching of ground units. The number of such occasions can be minimized, however. Although the 1959 data showed no strong evidence of when air tankers are not needed on initial attack, there were some indicators that showed they are <u>less likely</u> to be needed when

1. the Burning Index is below 9 (i.e., "low"),
2. the air temperature is below 80°F.,
3. winds are less than 10 miles per hour,
4. fires are burning in grass type or are confined to ground litter in dense woodland or timber types,
5. fires are burning on flat or gentle terrain,
6. crew getaway and travel time is less than 10 minutes.

ALTHOUGH THE ANALYSIS IS BASED PARTIALLY ON SUBJECTIVE JUDGMENT AND PARTIALLY ON OBJECTIVE DATA, IT IS FELT THAT THE CONCLUSIONS REACHED ARE AT LEAST GOOD INDICATORS AND CAN HELP FIRE CONTROL PERSONNEL TO MAKE DECISIONS IN SPECIFIC SITUATIONS.

INFORMATION OBTAINED FROM THE ANALYSIS

WHILE ONE YEAR'S DATA CANNOT BE CONSTRUED AS BEING CONCRETE EVIDENCE, ANALYSIS OF THE 1959 AIR TANKER PROGRAM DID HELP TO SUPPORT TENTATIVE GUIDELINES USED BY FIRE ADMINISTRATORS IN THE PAST AND ALSO POINTED OUT A FEW NEW AREAS FOR STRONG CONSIDERATION. ONLY THROUGH CONTINUED AND LONG-TERM EVALUATION OF ITS AIR TANKER PROGRAM CAN THE DIVISION HOPE TO REFINE EVEN FURTHER ITS USE GUIDELINES AND TO DETERMINE ON A STATISTICAL BASIS THE CONDITIONS UNDER WHICH AIR TANKERS SHOULD BE USED AND THE MANNER IN WHICH THEY SHOULD BE USED IN ORDER TO HELP REDUCE OVERALL FIRE COSTS.

THE FOLLOWING POINTS SEEMED TO BE MOST STRONGLY EVIDENT FROM ANALYSIS OF THE 1959 AIR TANKER PROGRAM DATA.

PLANNING AN AIR TANKER PROGRAM

1. TYPE OF AIR TANKER TO USE:

   THE CHOICE OF WHICH TYPE OR TYPES OF AIR TANKERS TO USE OFTEN WILL BE DICTATED WHOLLY BY AVAILABILITY OF AIRCRAFT OR BY AVAILABLE FUNDS. IF A CHOICE IS POSSIBLE, SEVERAL FACTORS SHOULD BE CONSIDERED:

   A) DISTANCES BETWEEN AVAILABLE AIRPORTS. THE DATA INDICATED THAT THE OPTIMUM DISTANCE BETWEEN AIRPORTS FOR SMALLER AIR TANKERS (300 GALLON CAPACITY OR LESS) IS 40 TO 60 MILES; FOR LARGER AIR TANKERS, 60 TO 80 MILES.

   B) TOPOGRAPHY. WHERE THE TERRAIN IS CUT GENERALLY BY A LARGE NUMBER OF DEEP, NARROW CANYONS, MORE MANEUVERABLE AIR TANKERS, SUCH AS THE N3N, ARE DESIRABLE.

   C) FIRE BEHAVIOR AND VEGETATIVE TYPE. WHEN FIRE BEHAVIOR IS COMMONLY EXTREME WITH HIGH HEAT INTENSITY AND A FAST RATE OF SPREAD IN HEAVY FUELS, AIR TANKERS WITH LARGER LOAD CAPACITIES (600 GALLONS OR MORE) ARE DESIRABLE.

   D) AIR TANKER CAPABILITY. AIR TANKER TYPES VARY CONSIDERABLY IN THEIR CAPABILITY TO DELIVER RETARDANT TO A FIRE. ALL OTHER THINGS BEING EQUAL, THE LARGER, FASTER AIR TANKER WILL ALWAYS DELIVER MORE RETARDANT PER UNIT TIME THAN THE SMALLER, SLOWER TANKER. THIS GENERAL STATEMENT, HOWEVER, DOES NOT TAKE INTO ACCOUNT THOSE FACTORS WHICH TEND TO MAKE AN INDIVIDUAL DROP EFFECTIVE: PILOT ABILITY, TANK AND GATE CONFIGURATION, MANEUVERABILITY OF THE AIRCRAFT AT THE SCENE OF THE FIRE, ETC. THESE FACTORS ARE EXTREMELY IMPORTANT AND MUST BE WEIGHED IN JUDGING THE OVERALL CAPABILITIES OF AIR TANKERS UNDER CONSIDERATION FOR USE.

   DISREGARDING EFFECTIVENESS OF INDIVIDUAL DROPS, THE DATA FROM THE DIVISION'S 1959 OPERATIONS SHOWING THE PERFORMANCES BY DIFFERENT AIR TANKER TYPES AVERAGED OVER ALL FIRES ARE SUMMARIZED IN TABLE 2.

TABLE 2. PERFORMANCE OF AIR TANKERS ON DIVISION OF FORESTRY FIRES, 1959

TANKER TYPE	CAPACITY (GALS.)	AVERAGE SPEED (MPH)	AVERAGE DOWN TIME (MINS.)	AVERAGE DELIVERY (GALS/MIN.)	GALS/MIN. RATIO	COST/ HOUR	COST/HR. RATIO
N3N	200	90	6	6	1.00	$ 95	1.00
TWIN BEECH	300	140	9	10	1.67	120	1.26
TBM	600	150	12	18	3.00	220	2.32
F7F	800	180	15	25	4.17	350	3.69

ACTUALLY, THE COLUMN "AVERAGE DELIVERY, GALLONS/MINUTE" DOES NOT TELL A TRUE STORY SINCE THE CAPABILITY OF DIFFERENT AIR TANKERS TO DELIVER RETARDANT TO A FIRE VARIES WITH VOLUME OF LOAD, RATE OF SPEED, NUMBER OF TRIPS TO THE FIRE ON A SUSTAINED OPERATION, DISTANCE TO THE FIRE FROM THE AIRPORT, AND AVERAGE DOWN-TIME NEEDED FOR REFILLING, SERVICING, MAINTENANCE, ETC., BETWEEN TRIPS. THESE FACTORS CAN BE COMBINED INTO A FORMULA WHICH WILL GIVE THE AIR PROGRAM ADMINISTRATOR ONE BASIS FOR PLANNING HIS AIR TANKER OPERATION. THIS FORMULA AND ITS APPLICATION TO THE DIVISION'S 1959 AIR TANKER OPERATION DATA ARE DISCUSSED IN THE APPENDIX (PAGE_____).

2. AIR OPERATIONS MAP:

EACH DISPATCHER'S OFFICE SHOULD HAVE AN AIR OPERATIONS MAP WHICH WILL CONTAIN ALL THE SPECIALIZED INFORMATION RELATIVE TO THE USE OF AIR TANKERS, AND OTHER AIRCRAFT, ON FOREST FIRES. HERE ARE SOME OF THE THINGS PERTINENT TO AIR TANKER USE THAT SHOULD BE CONSIDERED FOR INCLUSION:

A. DELINEATION OF AREAS OF USE:

1) CERTAIN AREAS SHOULD BE DELINEATED WHERE AIR TANKER USE NORMALLY WILL BE EXCLUDED EXCEPT UNDER EXTRAORDINARY CONDITIONS. SUCH AREAS MIGHT INCLUDE THOSE PLACES WHERE HISTORICALLY THERE HAVE BEEN VERY FEW, IF ANY, LARGE FIRES; ZONE 3 AREAS; AREAS OF LOW VALUE; HIGHLY POPULATED AREAS WHERE HISTORICALLY THE LOCAL PEOPLE HAVE CONTRIBUTED TO FAST INITIAL ATTACK OR WHERE THE USE OF LOW FLYING AIRCRAFT COULD ENDANGER LIFE AND PROPERTY; AREAS WITHIN 10 MINUTES TRAVEL TIME OF CREWS (AND NOT INFLUENCED BY OTHER FACTORS); AREAS WHERE RESISTANCE TO CONTROL BY GROUND FORCES IS LOW; DEEP CANYONS WHERE NO AIR TANKER TYPE CAN MANEUVER SAFELY, ETC.

2) OTHER AREAS SHOULD BE DELINEATED WHERE AIR TANKERS NORMALLY WILL BE DISPATCHED ON INITIAL ATTACK AT ALL TIMES. SUCH AREAS MIGHT INCLUDE HIGH VALUES; HIGH HAZARDS; AREAS OVER 20 MINUTES TRAVEL TIME FROM CREW BASES; AREAS WHERE THERE IS A HIGH RESISTANCE TO CONTROL BY GROUND FORCES, ETC.

3) WHEN FIRES OCCUR IN ANY AREA NOT DELINEATED AS "ALMOST NEVER" OR "ALMOST ALWAYS", AIR TANKERS SHOULD BE DISPATCHED ON INITIAL ATTACK ACCORDING TO THE BEST JUDGMENT OF THE DISPATCHER, BASED UPON HIS KNOWLEDGE OF ALL FACTORS CONTRIBUTING TO THE PROBABILITY OF SUCCESSFUL AND EFFICIENT AIR TANKER USE ON FOREST FIRES. THESE FACTORS ARE DISCUSSED UNDER "INITIAL ATTACK DISPATCHING" ON PAGE_____.

B. THE LOCATION OF DEEP, NARROW CANYONS. ONLY THE MORE MANEUVERABLE AIR TANKERS AND MORE EXPERIENCED PILOTS SHOULD BE USED IN SUCH PLACES. SOME CANYONS MAY DICTATE THAT NO AIR TANKERS COULD BE USED SAFELY. (SEE A, 1, ABOVE).

C. POWER AND TELEPHONE LINES OVER 25 FEET ABOVE THE GROUND

D. BROAD VEGETATIVE TYPES. THESE SHOULD BE NOTED EITHER ON THE AIR OPERATIONS MAP OR ON A SEPARATE MAP. AIR TANKERS IN 1959 WERE ALMOST ALWAYS EFFECTIVE ON FIRES OCCURRING IN GRASS, WOODLAND, OR SCATTERED BRUSH TYPES. ON THE OTHER HAND THEY WERE INEFFECTIVE ABOUT AS MANY TIMES AS THEY WERE EFFECTIVE ON FIRES IN DENSE BRUSH; IN SUCH TYPES THEY SHOULD THEREFORE NOT ALWAYS BE RELIED UPON TO PERFORM AN EFFECTIVE CONTROL JOB. THEIR EFFECTIVENESS ON TIMBER FIRES VARIED CONSIDERABLY: IN 1959 THEIR ACTION WAS USUALLY INEFFECTIVE ON THE PERIMETERS OF HOT, CROWNING TIMBER FIRES ALTHOUGH THEY PERFORMED SEVERAL GOOD JOBS OF HITTING SPOT FIRES IN THE ADVANCE OF THE MAIN FIRE. LARGER TYPES OF AIR TANKERS ARE MORE LIKELY TO BE SUCCESSFUL IN THESE SITUATIONS, BUT EVEN THEY CANNOT BE RELIED UPON IN EVERY CASE. IF FIRE WAS CONFINED TO GROUND COVER BENEATH THE TIMBER CANOPY, AIR TANKERS WERE USUALLY NOT NEEDED BECAUSE OF EASE OF CONTROL BY GROUND FORCES OR BECAUSE THE RETARDANT COULD NOT REACH THE GROUND FUEL.

3. COMMUNICATIONS:

GOOD COMMUNICATIONS FROM GROUND TO AIR, AIR TO AIR, AND ONE AGENCY TO ANOTHER IS AN ABSOLUTE NECESSITY FOR SUCCESSFUL USE OF AIR TANKERS. NO AIR TANKER PROGRAM SHOULD BE ATTEMPTED WITHOUT PLANNING AND PROVIDING AN ADEQUATE COMMUNICATIONS SYSTEM, INCLUDING A SEPARATE AIR NET. THIS FACT WAS AGAIN EVIDENCED TIME AFTER TIME IN 1959.

4. EVALUATION OF AIR TANKERS AND PILOTS:

AN EVALUATION OF AIR TANKERS AND PILOTS SHOULD BE PLANNED. IF AFTER A REASONABLE TRAINING PERIOD (E.G., 50 DROPS) A TANKER AND/OR PILOT DO NOT APPEAR TO BE PERFORMING A SATISFACTORY JOB, THEIR DISMISSAL SHOULD BE SERIOUSLY CONSIDERED.

5. ADEQUATE FACILITIES:

DOWN-TIME OF AIR TANKERS BETWEEN TRIPS TO A FIRE ON A SUSTAINED OPERATION SHOULD BE REDUCED TO A REASONABLE MINIMUM. A SUGGESTED GOAL IS A MAXIMUM DOWN-TIME OF FIVE MINUTES. FACILITIES AND PERSONNEL SHOULD BE PLANNED AND BUDGETED TO MEET THIS GOAL FOR THE LARGEST AIR TANKER TYPE CONTEMPLATED FOR USE AT ANY GIVEN AIRPORT. THIS PLANNING MAY INCLUDE THE NEED FOR LARGER TRANSFER PUMPS, MORE THAN ONE TRANSFER PUMP, LARGER LOADING HOSES, ADDITIONAL LOADING HOSES MAKING IT POSSIBLE TO USE TWO OR MORE HOSES TO LOAD THE LARGER SHIPS, MORE ADEQUATE MIXING AND STORING FACILITIES, BETTER SERVICING FACILITIES, ETC.

1959 DATA ON DOWN-TIME FOR VARIOUS AIR TANKER TYPES IS INCLUDED IN TABLE 2 AND SHOW THAT THE TIMES VARIED FROM AN AVERAGE OF SIX MINUTES FOR N3N'S TO AN AVERAGE OF 15 MINUTES FOR F7F'S. THIS DOWN-TIME IS WASTED TIME INSOFAR AS EFFECTIVE ACTION ON THE FIRE IS CONCERNED. ONE REASON OFTEN GIVEN BY FIRE MANAGERS FOR THE INEFFECTIVENESS OF AIR TANKERS ON FIRES IN 1959 WAS, "ROUND-TRIP TIME WAS TOO LONG. THE FIRE FLANKED THE DROPS WHILE THE AIR TANKERS WERE GONE. JUST A FEW MINUTES LESS FOR ROUND-TRIPS COULD HAVE RESULTED IN SUCCESSFUL ACTION BY THE AIR TANKERS."

Initial attack dispatching

1. Quick dispatching:

Air tankers should be dispatched on initial attack in much the same manner as any other tool, i.e., the dispatcher must ask himself for each fire reported, "What is the probable situation? What fire tool (crew, bulldozer, air tanker, helicopter, patrolman, etc.) is most likely to be an economic success in this situation? Which tool can be expected to reach the fire first?" If the answers to these questions indicate the air tankers should be dispatched at once, then they should be sent. If there is a high degree of uncertainty, then they should not be dispatched unless subsequently requested by the fire manager. The 1959 data showed in several ways that air tankers, when needed, were most effective when they were dispatched quickly and arrived at the fires while they were still small (fig. 7). Many times ground crew leaders and fire managers reported "another minute or two would have meant the difference between success or failure" of air tankers in helping to keep fire size small in the initial attack stages.

Fig. 7. Air tankers are most effective when they arrive at a fire while it is still small.

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2. Vegetative type:

The 1959 data showed air tankers were very effective on fires in grass, woodland, or scattered brush types; effective only about half the time on fires in dense, heavy brush; and varied considerably in their need and effectiveness on timber fires. These factors should be considered in the light of all other conditions at the time of dispatching.

3. Wind:

Winds over 20 miles per hour sharply reduced air tanker effectiveness. On at least two or three fires in 1959, however, they were judged to be the most important tool in holding fires to much smaller acreages than was expected under wind conditions of 30-40 miles per hour. When winds were less than 10 miles per hour, air tankers were not needed a third of the time.

4. Topography:

In 1959 the air tankers were almost always judged either "effective" or "not needed" on fires occurring in topography judged to be flat, gently sloping, or rolling. Ineffectiveness increased sharply when terrain was judged as steep or very steep. At least some of this ineffectiveness was due to improper tactical use of air tankers in such terrain, such as directing the tankers to drop across the head of a fire moving swiftly upslope; such a fire normally spotted across the drop almost at once, especially in heavier fuel types. More often success was attained by dropping along a bench or at the ridge where the fire spread slowed. Some of the ineffectiveness was also due to the inability of the tankers to maneuver and perform well in steep terrain.

5. Temperature:

Initial attack air tanker action in 1959 was judged "not needed" in four out of ten cases when the air temperature was less than 80°F. This ratio

WAS DECREASED SHARPLY TO THE OVERALL RATIO OF LESS THAN THREE OUT OF TEN CASES WHEN THE AIR TEMPERATURE WAS 80°F OR GREATER.

6. BURNING INDEX:

THE CALIFORNIA BURNING INDEX WAS NOT TOO WELL CORRELATED WITH AIR TANKER EFFECTIVENESS. THE TANKERS GENERALLY WERE NOT USED WHEN THE INDEX WAS BELOW 9 (I.E., "LOW"), BUT THE FEW TIMES THEY WERE USED IN THIS CATEGORY FOUND THEM JUDGED ABOUT EQUALLY "EFFECTIVE" OR "NOT NEEDED", BUT NEVER "INEFFECTIVE." THE DATA SHOWED THAT THEY WERE VIRTUALLY ALWAYS NEEDED WHEN THE INDEX WAS ABOVE 26 (I.E., "EXTREME"), ALTHOUGH THEY WERE EFFECTIVE ON ONLY ABOUT HALF THE FIRES BURNING IN THIS CATEGORY. NO COMPARISON OF EFFECTIVENESS TO INTENSITY INDEX WAS MADE, AND IT IS POSSIBLE THAT BETTER CORRELATION MAY BE FOUND WITH THIS INDEX THAN WITH THE TOTAL BURNING INDEX FOR BRUSH AND TIMBER FIRES.

7. TIME OF DAY:

THE 1959 DATA SHOWED FAIR CORRELATION BETWEEN AIR TANKER EFFECTIVENESS AND TIME OF DAY THAT FIRES WERE REPORTED. THE GREATEST DEGREE OF INEFFECTIVENESS OCCURRED ON FIRES REPORTED BETWEEN 1000 AND 1400 P.D.T. (AIR TANKERS WERE RARELY PLACED ON STANDBY READY FOR USE PRIOR TO 1000 P.D.T. AND OCCASIONALLY NOT UNTIL 1200 P.D.T., DEPENDING ON THE BURNING INDEX). EFFECTIVENESS INCREASED SHARPLY ON FIRES REPORTED AFTER 1400 P.D.T.

8. CREW GETAWAY AND TRAVEL TIME:

AIR TANKERS OFTEN WERE NOT NEEDED WHEN CREW GETAWAY AND TRAVEL TIME WERE LESS THAN 10 MINUTES, ALTHOUGH THIS WAS TRUE IN ONLY A THIRD OF THE CASES IN 1959.

9. DISTANCE TO FIRE:

AIR TANKERS WERE ALMOST NEVER JUDGED "INEFFECTIVE" WHEN THE DISTANCE TO THE FIRE FROM THE AIRPORT WAS 20 MILES OR LESS. INEFFECTIVENESS INCREASED SHARPLY ABOVE THAT DISTANCE, ALMOST EQUALING THE NUMBER OF CASES IN WHICH AIR TANKERS WERE EFFECTIVE. THIS POINT SUPPORTS THE GENERAL PRINCIPLE THAT AIR TANKERS ARE MOST EFFECTIVE WHEN THEY REACH FIRES QUICKLY.

10. RATE OF SPREAD:

AIR TANKERS WERE VIRTUALLY ALWAYS NEEDED WHEN A FIRE'S RATE OF SPREAD WAS JUDGED AS FAST OR EXTREME, ALTHOUGH THERE WAS ALMOST AN EVEN CHANCE OF THEIR BEING JUDGED "EFFECTIVE" OR "INEFFECTIVE" IN THEIR CONTROL CONTRIBUTION. RARELY WERE THE AIR TANKERS INEFFECTIVE ON FIRES JUDGED TO BE BURNING SLOW OR MODERATELY FAST.

11. SPECIAL CASE:

AIR TANKERS USUALLY WERE NOT NEEDED ON FIRES WHICH STARTED UNDER THE COMBINED CONDITIONS OF BEING LATE IN THE DAY, ON THE SHADED SIDES OF RIDGES, AND IN DENSE WOODLAND OR TIMBER. THESE COMBINED CONDITIONS TENDED TO CONTRIBUTE TO RISING RELATIVE HUMIDITY AND FINE FUEL MOISTURE CONTENT AND TO LOWERING TEMPERATURE AND BURNING INDEX, RESULTING IN A LOW RATE OF FIRE PERIMETER SPREAD WHICH COULD BE HANDLED READILY BY GROUND FORCES.

12. WET LIGHTNING FIRES:

AIR TANKERS WERE OFTEN NOT NEEDED IN 1959 ON LIGHTNING FIRES STARTED BY WET THUNDERSTORMS FROM WHICH CONSIDERABLE MOISTURE REACHED THE GROUND. NORMALLY

EVEN A LARGE NUMBER OF SUCH FIRES CAN BE PICKED UP BY GROUND FORCES. IF ALL LIGHTNING FIRES ARE NOT PICKED UP WITHIN 24 HOURS, OR IF THE BRUSH OR TIMBER INTENSITY INDEX IS HIGH PREVIOUS TO THE STORM, AIR TANKERS WILL LIKELY BE NEEDED. THE AMOUNT AND DISTRIBUTION OF PRECIPITATION ARE THE KEYS TO MAKING A DECISION IN THIS SITUATION.

AIR-GROUND COORDINATION

1. COMMUNICATIONS:

GOOD COMMUNICATIONS FROM GROUND-TO-AIR AND AIR-TO-AIR IS AN ABSOLUTE NECESSITY FOR THE SUCCESSFUL USE OF AIR TANKERS. UNTIL THE COMMUNICATIONS PROBLEM WAS SOLVED IN 1959, GROUND CREW LEADERS GAVE THIS REASON MOST OFTEN (AND IN THE STRONGEST LANGUAGE!) AS THE PRINCIPAL FACTOR CONTRIBUTING TO INEFFECTIVE USE OF AIR TANKERS. COORDINATION BETWEEN GROUND AND AIR FORCES IS ALMOST IMPOSSIBLE WITHOUT ADEQUATE COMMUNICATIONS.

2. DROP COORDINATOR:

THE ACTIVITY AND SAFETY OF AIR TANKERS ON A FOREST FIRE MUST BE CONTROLLED AT ALL TIMES BY THE DROP COORDINATOR. THE DROPCO MUST DETERMINE THE PRESENCE OF ALL AIRCRAFT ON A FIRE, MAINTAIN KNOWLEDGE OF THEIR LOCATION AT ALL TIMES, DIRECT THEIR ORBITING AND FLIGHT PATTERNS AND DIRECT THE RETARDANT DROPS OF THE AIR TANKERS. TO PERFORM THIS HIGHLY IMPORTANT JOB AND TO OBTAIN MAXIMUM EFFICIENCY OF A VERY COSTLY TOOL REQUIRES THE EFFORTS OF A PERSON WHO IS BOTH A STRONG SUPERVISOR AND AN EXPERIENCED FIRE CONTROL TECHNICIAN, AND WHO POSSESSES SUFFICIENT RANK IN THE ADMINISTRATIVE HEIRARCHY TO COMMAND RESPECT OF DECISION FROM BOTH GROUND AND AIR PERSONNEL.

3. FIRE BOSS-DROP COORDINATOR RELATIONSHIP:

THE FIRE BOSS AND THE DROP COORDINATOR, OR THE AIR TANKER PILOTS IN THE ABSENCE OF A DROP COORDINATOR, MUST AT ALL TIMES COORDINATE CLOSELY THE GROUND AND AIR SUPPRESSION EFFORTS (FIG. 8.). MANY TIMES IN 1959 EITHER THE GROUND OR THE AIR FORCES CANCELLED THE GOOD EFFORTS OF THE OTHER THROUGH THE LACK OF COORDINATION OF ACTIVITY BETWEEN THE TWO.

FIG. 8. THE FIRE CONTROL EFFORTS OF AIR AND GROUND FORCES MUST BE CLOSELY COORDINATED FOR MAXIMUM EFFECTIVENESS.

4. COORDINATION AMONG PILOTS:

AIR TANKER PILOTS SHOULD CLOSELY COORDINATE THEIR ACTIVITIES NOT ONLY WITH GROUND UNITS BUT ALSO AMONG THEMSELVES. THEY SHOULD NOT DROP INDISCRIMINATELY BUT SHOULD ATTEMPT TO BUILD CONTINUOUS RETARDANT LINES UNLESS THEY HAVE BEEN GIVEN SPECIFIC INSTRUCTIONS TO THE CONTRARY.

5. SERIES OF SETS:

IF THERE IS A SERIES OF FIRE SETS, AIR TANKERS MAY BEST BE USED ON THE SMALLEST AND/OR THE MOST ISOLATED FIRE WHILE THE BULK OF THE GROUND UNITS ATTACK THE LARGER AND MORE ACCESSIBLE FIRE OR FIRES. THE AIR TANKERS SHOULD ATTACK THE ISOLATED FIRE ONLY IF THEY CAN BE REASONABLY EXPECTED TO CONTAIN IT ENTIRELY OR CAN RELY UPON EARLY GROUND SUPPORT.

6. CRITIQUES:

IT IS IMPORTANT THAT GROUND AND AIR PERSONNEL HAVE CRITIQUES AS OFTEN AS POSSIBLE FOLLOWING FIRES ON WHICH AIR TANKERS ARE USED. TOO OFTEN IN THE PAST, PROBLEMS BETWEEN GROUND AND AIR FORCES HAVE BEEN REPEATED AND COMPOUNDED NEEDLESSLY. FREQUENT, SHORT MEETINGS CAN BE THE BEST MEANS OF OBTAINING MAXIMUM COORDINATION BETWEEN GROUND AND AIR FORCES.

TACTICAL USE OF AIR TANKERS ON FIRES

1. PRIMARY CRITERION OF USE:

THE PRIMARY CRITERION IN THE USE OF AIR TANKERS ON FOREST FIRES IS TO USE THEM IN THE SAME MANNER AS ANY OTHER FIRE TOOL, WITH ESSENTIALLY THE SAME STRATEGY AND TACTICS. COMMON SENSE AND FIRE SENSE WILL ALWAYS BE THE BEST GUIDES AND ARE INTENDED TO BE IMPLIED IN THE FOLLOWING CRITERIA OF AIR TANKER USE.

2. LINE LOCATION:

AS WITH ANY OTHER TOOL, AIR TANKERS SHOULD BE DIRECTED TO ATTACK THAT PORTION OF THE FIRE LINE WHERE THEIR CHANCE OF SUCCESS IN HALTING OR SLOWING THE FIRE'S SPREAD IS MAXIMUM. FIRST CHOICE OF ATTACK SHOULD ALWAYS BE THE HEAD OF A FIRE BUT ONLY IF SUCH AN ATTACK CAN REASONABLY BE EXPECTED TO HOLD THE FIRE WITHOUT THE DANGER OF BEING OUTFLANKED AND OF COMPOUNDING THE FIRE CONTROL PROBLEM.

IF THERE IS A CHOICE, AIR TANKERS SHOULD BE DIRECTED TO CONSTRUCT THEIR RETARDANT LINE IN THE LIGHTER FUELS WHERE THE 1959 DATA SHOWED THEY WERE MOST EFFECTIVE. OFTEN THIS WILL MEAN MAKING A CONTINUOUS, INDIRECT LINE AT SOME DISTANCE FROM THE FIRE. MANY TIMES IN THE PAST, RETARDANT LINES WHICH WERE BUILT TOO CLOSE TO THE FIRE LINE WERE OUTFLANKED BY THE FIRE BEFORE THEY WERE COMPLETED. THE ACTUAL DISTANCE OF THE DROPS FROM THE FIRE DEPENDS LARGELY UPON THE FUEL TYPES IN THE AREA, INTENSITY AND RATE OF SPREAD OF THE FIRE, POSSIBLE FOLLOW-UP BY GROUND FORCES, NUMBER AND SIZE OF AIR TANKERS INVOLVED IN THE ACTION, AND ROUND TRIP TIME TO THE REFILL AIRPORT.

3. SMALL FIRES:

AIR TANKERS ARE MOST SUCCESSFUL ON SMALL FIRES WHICH OFTEN CAN BE ENTIRELY SURROUNDED AND HELD BY RETARDANT DROPS. IF, HOWEVER, NO GROUND UNITS ARE IMMEDIATELY AVAILABLE FOR FOLLOW-UP ACTION AND THE AIR PERSONNEL FEEL THEY CANNOT ENTIRELY CONTAIN A FIRE PERIMETER WITH THEIR FIRST SERIES OF DROPS, THEY SHOULD USUALLY ATTACK THE FLANKS OF A FIRE RATHER THAN ATTEMPT TO STOP THE HEAD. IF THERE CAN BE NO EARLY FOLLOW-UP ACTION, EVEN A SLOW-MOVING FIRE WILL OFTEN OUTFLANK A DISCONTINUOUS RETARDANT LINE LAID ACROSS ITS HEAD AND POSSIBLY RESULT IN TWO HEADS SPREADING IN DIFFERENT DIRECTIONS.

4. LARGE FIRES:

SELDOM ARE DROPS SUCCESSFUL ACROSS THE HEADS OF LARGE FIRES. AIR TANKERS CAN BE DIRECTED TO PERFORM THEIR MOST EFFECTIVE ACTION ON FLANKS, HOT SPOTS, AND SPOT FIRES. THEY CAN ALSO BE USED EFFECTIVELY IN PRETREATING RIDGES WELL IN ADVANCE OF THE MAIN FIRE OR IN WIDENING ESTABLISHED CONTROL LINES.

5. FAST MOVING FIRES:

ON FAST MOVING FIRES AIR TANKERS CAN BE USED MOST EFFECTIVELY ON THE FLANKS. HITTING THE HEAD OF ANY SUCH FIRE WILL USUALLY RESULT IN SPLITTING THE ONE

HEAD INTO TWO OR MORE HEADS UNLESS THERE CAN BE IMMEDIATE FOLLOW-UP BY ADEQUATE GROUND FORCES. EVEN FLANKING ACTION SHOULD NOT BE DONE INDISCRIMINATELY BUT SHOULD BE TIED TO AN ESTABLISHED FIRE-BREAK AND BE LAID CONTINUOUSLY UNLESS THERE IS GOOD REASON TO PERFORM HOT-SPOTTING ACTION.

6. FIRE ON STEEP SLOPE:

HITTING THE HEAD OF ANY HOT FIRE BURNING SWIFTLY UP A STEEP SLOPE IN HEAVY FUELS IS RARELY EFFECTIVE. IN THESE CASES MORE EFFECTIVE ACTION CAN USUALLY BE TAKEN BY PRETREATING THE RIDGE OR A BROAD BENCH WHERE THE FIRE SPREAD WILL SLOW DOWN. A CHANGE TO A LIGHTER FUEL TYPE MAY ALSO PRESENT POSSIBILITIES FOR PRETREATMENT AND MORE CERTAIN CONTROL.

7. HIGH INTENSITY FIRES:

ON HIGH INTENSITY FIRES OR ON FIRES BURNING IN HEAVY FUELS, VOLUME OF RETARDANT MAY BE DESIRABLE, REQUIRING EITHER LARGER AIR TANKERS OR AN OVERLAPPING OF DROPS OF SMALLER AIR TANKERS.

8. SUSTAINED ACTION:

SUSTAINED USE OF AIR TANKERS ON LARGE FIRES OVER A PERIOD OF TWO OR MORE DAYS REQUIRES CAREFUL PLANNING BY THE FIRE BOSS. IF AIR TANKER USE IS PROBABLE FOR ALL DAYLIGHT HOURS (12-14 HOURS), PLANS MUST BE MADE FOR PILOT RELIEF, ADEQUATE AIRCRAFT SERVICING AND MAINTENANCE, ADEQUATE SUPPLIES OF RETARDANTS, AND POSSIBLE RELIEF OF AIRPORT FACILITY PERSONNEL DEPENDING ON THE SIZE OF THE PROPOSED OPERATION. IF AIR TANKERS ARE TO BE NEEDED FOR DROPPING AS SOON AS THE FIRST LIGHT OF DAY PERMITS LOW FLYING IN SAFETY, THEN PLANS MUST BE MADE TO SERVICE AND MAINTAIN AIRCRAFT DURING THE PREVIOUS NIGHT AND TO ARRANGE FOR TAKE-OFF FROM THE AIRPORT SO THAT THE AIR TANKERS ARE ORBITING OVER THE FIRE AT DAWN, PREPARED FOR DROPPING RETARDANT AS SOON AS IT CAN BE SAFELY APPLIED AND AIR ACTION CAN BE COORDINATED WITH GROUND FORCES.

9. MOP-UP ACTION:

RARELY SHOULD AIR TANKERS BE USED ON MOP-UP ACTION WHICH USUALLY CAN BE DONE MUCH BETTER BY GROUND FORCES. THEY ARE TOO EXPENSIVE A TOOL TO USE IN SUCH ACTION UNLESS THERE IS AN IMPORTANT NEED TO COOL A PARTICULARLY THREATENING PIECE OF LINE.

DROP TECHNIQUES

1. OPTIMUM GROUND PATTERN:

EACH PILOT SHOULD BE WELL ACQUAINTED WITH THE ALTITUDES (ABOVE THE TOP OF THE VEGETATION) AND AIR SPEEDS AND GATE OPENINGS FOR HIS SPECIFIC AIR TANKER WHICH PRODUCE THE OPTIMUM GROUND PATTERN FOR VARIOUS VEGETATIVE TYPES AND FIRE SITUATIONS. THESE THREE FACTORS VARY FOR INDIVIDUAL AIR TANKERS. NORMALLY THE SAME ALTITUDE AND SPEED WILL BE DESIRABLE FOR MOST FIRE SITUATIONS. IN GRASS OR IN OTHER FUEL TYPES GIVING LOW INTENSITY FIRES, THE CONCENTRATION OF RETARDANT PER UNIT OF GROUND AREA MAY BE DECREASED CONSIDERABLY; THEREFORE IT IS DESIRABLE TO INCREASE BOTH HEIGHT AND SPEED AND/OR DECREASE GATE OPENING, CAUSING A GIVEN VOLUME OF RETARDANT TO PRODUCE A LONGER PATTERN WITH LOWER CONCENTRATION OF RETARDANT PER UNIT AREA, THUS MAKING MORE EFFICIENT USE OF THE LOAD. IT MUST BE REMEMBERED THAT G-LOADING CONSIDERABLY ALTERS THE DROP PATTERN AND SHOULD BE AVOIDED WHENEVER A DROP CAN BE MADE FROM FLIGHT PARALLEL TO THE GROUND SURFACE.

2. Low drops:

All drop tests to date show that no air tanker should fly lower than 50 feet above the top of the vegetation at any time. Drops made from a lower altitude produce a small ground pattern with a much higher than normally necessary concentration of retardant, thus decreasing efficiency of the load. In 1959 low drops on at least four different Division of Forestry fires were blamed for causing the fire to spread quickly when hit by the prop wash of air tankers. Low drops have also caused fatal and near-fatal accidents to personnel and have damage equipment (fig. 9). While low drops will produce a higher concentration of retardant per unit area (over a smaller area for a given load), such a concentration, if deemed desirable, should be obtained by using a larger capacity air tanker or by overlapping drops of smaller tankers; it should never be obtained by dropping from a lower altitude.

Fig. 9. Retardants dropped at too low an altitude can damage equipment

3. Judging altitude:

Tests have shown that rarely can pilots accurately judge low altitudes. A continuous effort must be made, therefore, to train pilots in their ability to judge such key heights as 50, 75, and 100 feet. One way of learning is to fly adjacent to objects whose heights are known, such as high power lines, trees, or towers.

4. Drops at right angles to fire line:

Drops should not be made at right angles to a fire line unless the air tanker is hot-spotting a small area and there is no other good approach. Such drops make use of only the width of the ground pattern rather than the length, wasting retardant. Also such drops often enter into the convection column of the fire and are carried upward, doing no good toward helping to suppress the fire.

5. High winds:

When operating in winds above 20 miles per hour, air tankers should fly into the wind for safety of operation, allowing for drift of the retardant when dropping.

Safety

1. Flying hazards:

Steep topography and deep canyons, dense smoke, high timber and snags, shifting and high velocity winds, and turbulent air are all definite flying hazards and were reported often in 1959 as causing high drops and consequent drifting of the retardant into ineffective ground patterns. Occasionally any one of these factors may restrict or exclude the use of air tankers.

2. Thunderclouds:

Thunderclouds in the vicinity of a fire will create dangerous down-drafts which not only are a hazard to aircraft but also may cause sudden shifts in fire spread. Such situations were reported several times in 1959.

3. TELEPHONE AND POWER LINES:

THE LOCATION OF HIGH TELEPHONE AND POWER LINES IN OR ADJACENT TO A FIRE AREA SHOULD BE COMMUNICATED TO AIR TANKERS FLYING TOWARD THEM BY EITHER THE DISPATCHER, WHO SHOULD HAVE THIS INFORMATION ON HIS AIR OPERATIONS MAP, OR PERSONNEL ALREADY ON THE FIRE.

4. NEARBY AIRPORTS:

THE PROXIMITY OF AIRPORTS WITH HEAVY TRAFFIC CAN BE A DEFINITE HAZARD TO AIR OPERATIONS ON A FOREST FIRE. THIS IS PARTICULARLY TRUE WHEN FIRES OCCUR NEAR MILITARY AIR BASES WHERE MANY JET AIRCRAFT REQUIRE A LARGE RADIUS FOR ORBITING AND APPROACHING THEIR BASE OF OPERATIONS. DISPATCHERS SHOULD RECOGNIZE THESE SITUATIONS (BY PREVIOUSLY NOTING SUCH MILITARY BASES ON THE AIR OPERATIONS MAP) AND COMMUNICATE THE POTENTIAL DANGER BOTH TO AIRCRAFT OPERATING ON THE FIRE AND TO THE AIR CONTROL PERSONNEL AT THE MILITARY BASE.

5. LOW FLYING:

THE DANGERS OF AIR TANKERS FLYING BELOW 50 FEET ABOVE THE VEGETATION HAS ALREADY BEEN NOTED IN THE SECTION ON DROP TECHNIQUES.

6. CONTROL OF AIRCRAFT ACTION:

THE NEED FOR ADEQUATE COMMUNICATIONS TO PROVIDE COORDINATION OF EFFORT, GROUND-TO-AIR, AIR-TO-AIR, AND AGENCY-TO-AGENCY, HAS ALREADY BEEN STRESSED. ADEQUATE COMMUNICATIONS ARE ALSO NECESSARY FOR SAFETY OF OPERATION. AIRCRAFT OF ALL TYPES OPERATING ON A FOREST FIRE MUST BE CONTROLLED AT ALL TIMES BY ONE PERSON IN COMMAND (USUALLY THE DROP COORDINATOR) IF MID-AIR COLLISIONS ARE TO BE AVOIDED AND IF SAFE, COORDINATED FIRE CONTROL EFFORT IS TO BE MAINTAINED. INSTRUCTIONS FROM THE CONTROL OFFICER FOR ORBITING AND DROPPING MUST BE FOLLOWED IMPLICITLY BY THE AIR TANKER PILOT UNLESS HE FEELS THE INSTRUCTIONS ARE BEYOND THE CAPABILITIES OF HIS TANKER, IN WHICH CASE HE SHOULD SIMPLY INFORM THE CONTROL OFFICER OF THIS FACT AND AWAIT FURTHER INSTRUCTIONS. AIR TANKER PILOTS SHOULD KEEP THE DROP COORDINATOR INFORMED OF ANY POTENTIAL DANGERS THEY MAY NOTE.

7. DISAGREEMENTS:

ARGUMENTS AS TO TACTICS DURING THE TIME OF THE AIR OPERATION CAN ONLY CAUSE CONFUSION AND ENDANGER THE ENTIRE FIRE CONTROL JOB OF THE AIR TANKERS. THE DROP COORDINATOR WILL CONTROL AIR ACTIVITIES. ANY DISAGREEMENTS SHOULD BE DISCUSSED AT A CRITIQUE FOLLOWING THE END OF OPERATIONS.

USE OF FIRE RETARDANTS

TABLE 3 SHOWS THE USE OF RETARDANTS BY THE DIVISION OF FORESTRY IN 1959.

TABLE 3. RETARDANT USE BY DIVISION OF FORESTRY, 1959. (GALLONS).

DISTRICT	NO. DROPS	BORATE	BENTONITE	TOTAL
I	264	14,485	50,055	64,540
II	921	152,610	2,360	154,970
III	385	128,985	4,750	133,735
IV	100	22,620	-0-	22,620
V	3	1,600	-0-	1,600
VI	372	117,160	70,110	187,270
TOTALS	2,045	437,460	127,275	564,735

THE AVERAGE COST PER GALLON OF RETARDANT DELIVERED TO DIVISION FIRES IN 1959 BY VARIOUS AIR TANKER TYPES WAS AS FOLLOWS:

	BENTONITE	BORATE
AVERAGE COST OF DELIVERY	$.255	$.255
COST OF MATERIAL	.015	.166
TOTAL	$.270	$.421

NOTE THAT THE FIGURES REFLECT ONLY THE COST OF FLIGHT TIME AND THE COST OF THE DRY MATERIALS USED TO MIX THE RETARDANT SLURRY; THEY DO NOT INCLUDE THE COST OF STAND-BY TIME FOR AIR TANKERS NOR THE COST OF MIXING, STORING, AND LOADING THE RETARDANT.

ALTHOUGH THE DIVISION USED AIR TANKERS ON ABOUT 80 FEWER FIRES IN 1959 THAN IN 1958, THE TOTAL USE OF RETARDANT WAS ABOUT THE SAME FOR THE TWO YEARS. THE PRINCIPAL CHANGE WAS THE USE OF BENTONITE IN 1959, PARTICULARLY IN DISTRICTS I AND VI.

PROBLEMS WITH BENTONITE

1959 WAS THE FIRST YEAR IN WHICH BENTONITE WAS USED OPERATIONALLY IN LARGE QUANTITIES ON FOREST FIRES (PHILLIPS AND MILLER, 1959A). AS HAS BEEN THE EXPERIENCE OF FIRE FIGHTING AGENCIES WITH OTHER RETARDANTS IN THE PAST, DIFFICULTIES WERE ENCOUNTERED IN THE EARLY MIXING AND USE OF BENTONITE SLURRY (PHILLIPS AND MILLER, 1959B). THE TENDENCY BY ALL USING AGENCIES WAS TO MIX BENTONITE TOO THINLY, CAUSING IT TO DRIFT WHEN DROPPED FROM AIR TANKERS AND CONSIDERABLY DECREASING THE LENGTH OF TIME IT WOULD RETAIN AN EFFECTIVE QUANTITY OF WATER FOR FIRE RETARDING PURPOSES. THESE EARLY FAILURES AND MISUNDERSTANDINGS OF WHAT CONSTITUTED A "PROPER MIX" DISCOURAGED SOME USERS OF BENTONITE AND GAVE RISE TO MANY CONFLICTING STORIES OF ITS EFFECTIVENESS AS COMPARED TO BORATE.

These conflicting stories resulted in cooperative drop tests being conducted at Ramona Airport in San Diego by the California Air Attack Coordinating Committee (Davis, 1960).[1] Briefly, the results indicated that there was no significant difference between the drop characteristics of borate and bentonite when dropped from air tankers flying at various heights and speeds; viscosity ("thickness" of slurry) was more important than weight per gallon in producing good drop patterns of any retardant slurry; and increasing the height and speed of air tankers increased the drift of any retardant slurry dropped.

Improvement of bentonite slurry

The early use of too thin a bentonite slurry resulted in several failures, as previously noted:

> Mendocino #228[2]: "Bentonite was too dispersed when hitting the ground, although it did slow the fire considerably and stopped some spots completely."
>
> Lake #62: "Bentonite breaking into fine mist before hitting ground."

The same problems, however, can be encountered with borate slurry or any retardant that is mixed improperly:

> Lake #60: "Borate was too thin, Drifting in many cases."

Several weeks were needed before the fire agencies learned the proper proportions of bentonite and local water needed to produce as thick a slurry as possible that could still be moved by the available transfer pump. Water was found to be the most critical factor; hard water and alkaline water both required larger proportions of bentonite than normal. Division of Forestry personnel found .85 pounds of bentonite per gallon of water were needed at Ukiah in District I, whereas .9 pounds were needed with hard water at Ramona, and nearly 1.5 pounds with alkaline water at Hemet in District VI.

After the bentonite slurry was thickened to the proper viscosity, comments from the field were quite favorable:

> Sonoma #269: "Bentonite drops held fire for 90 minutes until crews arrived."
>
> Mendocino #220: "No areas observed where fire burned through bentonite or spotted over."
>
> San Diego #267: "Bentonite really doing a good job."
>
> Summary Report, 1959, Ramona Airport: "As a retardant bentonite was considered not to be able to hold like borate. However, I saw many times where bentonite held just as long as borate, and in some cases it held where fire had burned through borate drops."

[1] The California Air Attack Coordinating Committee includes representatives from the U. S. Forest Service Regional Office, Arcadia Equipment Development Center, Pacific Southwest Forest and Range Experiment Station, Los Angeles County Fire Department, and the Division of Forestry. The Committee's function is to coordinate in California research and equipment development in air attack on forest fires.

[2] Quotations are those of personnel who took part in fire control action on fires which are identified by name and number.

Tactical use of fire retardants

It is probable that both borate and bentonite will continue to be used as fire retardants in 1960, based upon experience in 1959.

1) Line-holding ability

Bentonite should be used either in direct attack or in indirect attack when the constructed line is likely to be reached by the fire within at least one or two hours at the most. Beyond that time bentonite no longer will hold sufficient water to retard fire spread:

> San Diego #224: "Pre-treated area with bentonite. Held for one hour and then fire burned through."

The actual lapsed time will vary up to a two hour period depending on the drying conditions, the amount of fuel and the fire's heat intensity. Bentonite should hold for the maximum period in light grass or for slower burning fires. At the other extreme bentonite, or any retardant, will not hold against the head of a fast moving, high intensity fire burning in heavy brush or crowning in timber. On such fires retardants should be dropped on the slower moving flanks.

In general, then, it can be said that either borate or bentonite can be used in most initial attack situations while only borate should be used when pre-treatment for periods of more than one and a half or two hours is desirable. The fact that bentonite slurry is 15 cents cheaper per gallon than borate slurry should be kept in mind.

2) Penetration

More complete tests have yet to be conducted to determine the penetrability of borate and bentonite. The Ramona tests indicated that viscosity may be more important than weight in the drop pattern of a retardant, but to date there is inconclusive evidence and conflicting reports from 1959 fires regarding penetration characteristics:

> Lake #61: "Retardant not penetrating real heavy brush." This was in early use of bentonite in District I when it was quite a thin slurry.
>
> Lake #73: "Bentonite was thick and giving good penetration."
>
> Mendocino #220: "Bentonite seemed to penetrate well."
>
> Summary Report, Ramona Airport: "Bentonite was used on initial attack but sometimes borate was called for by the fire boss for penetrating work."
>
> Calaveras #110: "Borate could not penetrate tall timber deeply enough to hold the ground fire."

At this stage of development of retardants, then, no specific recommendations can be made as to what characteristics a retardant should have in order to penetrate a dense timber or brush canopy well.

3) Visibility of retardants

Air tanker pilots should be able to detect previous drops so that they can

CONTINUE AN UNBROKEN LINE OF FIRE RETARDANT. BORATE IS IDEAL IN THIS RESPECT IN THAT ITS PARTICLES DRY RATHER QUICKLY AND LEAVE A HIGHLY VISIBLE WHITE COATING. BENTONITE PARTICLES, ON THE OTHER HAND, REMAIN WET FOR A LONG TIME AND, UNLESS THE SLURRY IS ARTIFICIALLY COLORED, DROPS CANNOT BE SEEN. PINK ANILINE DYE (RHODAMINE B) IS RECOMMENDED AS THE BEST COMPROMISE IN COLOR FOR BENTONITE SLURRY FOR ALL VEGETATIVE TYPES, BEING VISIBLE IN GRASS, BRUSH, AND TIMBER. IF THE MAJORITY OF FIRES ARE IN GRASS, A BRIGHTER RED ANILINE DYE WOULD BE PREFERABLE, ALTHOUGH IT DOES NOT SHOW UP WELL IN BRUSH OR TIMBER. IF THE MAJORITY OF FIRES ARE IN BRUSH OR TIMBER, YELLOW ANILINE DYE (AUROMINE O) WOULD BE PREFERABLE, ALTHOUGH IT SHOWS UP POORLY IN DRY GRASS (PHILLIPS AND MILLER, 1959B). IT IS PROBABLE THAT THESE SAME COLORS SHOULD APPLY WITH OTHER RETARDANTS THAT MAY BE DEVELOPED IN THE FUTURE.

FUTURE STUDIES

TESTS TO DATE BY THE PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION, WITH WHOM THE DIVISION OF FORESTRY IS ENGAGED IN A COOPERATIVE FIRE RETARDANT RESEARCH PROGRAM, SHOW THAT BORATE AND BENTONITE ARE THE BEST RETARDANTS PRESENTLY AVAILABLE. TESTS WILL BE CONTINUED DURING 1960, HOWEVER, WITH A VERMICULITE-BENTONITE MIXTURE, AMMONIUM PHOSPHATE, "VISCOUS WATER" (WATER PLUS VISCOSITY AGENTS FOR THICKENING) AND A BENTONITE-FOAMITE MIXTURE.

THE DIVISION WILL ALSO TAKE PART IN A COOPERATIVE STUDY OF RETARDANT DROP IMPACT WITH THE OTHER MEMBERS OF THE CALIFORNIA AIR ATTACK COORDINATING COMMITTEE. IT IS HOPED THAT THESE TESTS WILL POINT OUT SAFETY MEASURES THAT SHOULD BE TAKEN BY GROUND PERSONNEL LOCATED IN THE VICINITY OF AIR TANKER OPERATIONS AND ALSO POINT OUT DROP TECHNIQUES THAT SHOULD, OR SHOULD NOT, BE PRACTICED BY AIR TANKERS IN ORDER TO PROVIDE A NECESSARY DEGREE OF SAFETY TO GROUND PERSONNEL.

CURRENT STUDIES OF RETARDANT MIXERS BY THE ARCADIA EQUIPMENT DEVELOPMENT CENTER, U. S. FOREST SERVICE, MAY GIVE FURTHER CLUES FOR IMPROVING THE WATER-HOLDING ABILITY OF BENTONITE. INDICATIONS TO DATE ARE THAT COMPLETENESS OF HYDRATION OF THE DRY BENTONITE PARTICLES MAY BE DIRECTLY PROPORTIONAL TO THE ENERGY USED IN COMBINING THE BENTONITE AND WATER INTO A SLURRY. THE STUDIES SHOULD GIVE LEADS AS TO THE BEST METHODS OF MIXING SLURRIES.

OTHER QUESTIONS REMAIN CONCERNING FIRE RETARDANTS. WHILE THE RAMONA TESTS IN 1959 SHOWED THAT VISCOSITY WAS MORE IMPORTANT THAN WEIGHT IN PRODUCING A GOOD DROP PATTERN, THE EFFECT OF A LARGE RANGE OF VISCOSITIES HAS NOT YET BEEN DETERMINED. WE NEED TO KNOW WHAT RETARDANT CHARACTERISTICS ARE DESIRABLE TO GIVE MAXIMUM PENETRATION OF DENSE TIMBER AND BRUSH CANOPIES: VISCOSITY? WEIGHT PER GALLON? SOME OTHER FACTOR? PERHAPS COHESION, INDEPENDENT OF WEIGHT AND VISCOSITY, IS IMPORTANT IN PENETRATION AND IN FREE-FALL DROP PATTERNS. ALSO, EXACTLY WHAT CONCENTRATION OF DIFFERENT RETARDANTS ARE REQUIRED FOR FIRES BURNING WITH DIFFERENT INTENSITIES AND IN DIFFERENT FUEL TYPES? AT PRESENT WE KNOW LESS DENSE CONCENTRATIONS ARE NEEDED IN THE LIGHTER FUELS AND ON FIRES OF LOW HEAT INTENSITY. BUT WHAT ARE THE AMOUNTS OF RETARDANT NEEDED PER UNIT GROUND AREA UNDER DIFFERENT CONDITIONS? HOW CAN WE DIRECT AIR TANKER PILOTS SO THEY CAN PRODUCE MAXIMUM EFFICIENCY OF THEIR TOTAL RETARDANT LOAD UNDER VARYING FIRE CONDITIONS? THESE AND OTHER QUESTIONS MUST YET BE ANSWERED BEFORE IT CAN BE SAID WE ARE DOING THE BEST JOB POSSIBLE WITH FIRE RETARDANTS AND AIR TANKERS.

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APPENDIX

Formula for Measuring Theoretical Capability of Air Tankers to Deliver Retardant to a Forest Fire

As noted in the section, "Use of Air Tankers on Forest Fires," the capability of different air tankers to deliver retardant to a fire varies with volume of load, rate of speed, number of trips to the fire on a sustained operation, distance to the fire from the airport, and average down-time needed for refilling, servicing, maintenance, etc., between trips. These factors can be combined into a formula which can be used by an air program administrator as one basis for planning his air tanker operation:

$$C.I. = \frac{VN}{\left[\frac{120\ ND}{R}\right] + \left[T\ (N-1)\right]} = \frac{\text{Gallons retardant delivered}}{\text{minute}}$$

C.I. = Capability index, in gallons per minute
V = Capacity of air tanker, in gallons
N = number of trips made to fire on a sustained operation
D = distance to fire from airport, one-way, in miles
R = rate of speed of air tanker, in miles per hour
120 = conversion factor
T = average down-time at airport between trips of a sustained operation, in minutes

Explanation of Capability Index and Factors

1. C.I. = Capability Index. This index measures the theoretical or actual number of gallons of retardant capable of being delivered per minute by an air tanker. It permits comparing the performance of one air tanker with any other and can also be used to calculate the cost per hour ratio of one air tanker to any other for contracting purposes.

   According to the formula, C.I. varies with various distances to the fire and the number of trips made to any one fire. The factors R (rate of speed) and T (down-time between trips) are average figures and remain constant once they have been calculated for a given air tanker.

   The index assumes that all gallons of retardant delivered to a fire are dropped with equal accuracy and are equally effective. With present variations in pilot ability, condition of aircraft, and in tank and gate configurations, this assumption is not entirely correct. It will tend to become increasingly correct, however, as 1) pilots become equally experienced and able in their performance and 2) as aircraft owners continue to build new tanks and gates which will produce an optimum retardant pattern on the ground for their individual aircraft. Under the latter assumption a 400 gallon retardant drop will cover twice the ground area as a 200 gallon drop with equal effectiveness in all parts of the drop pattern. This goal is theoretically possible with the proper tank and gate design and with an air tanker flying at its optimum height and speed.

   Also assumed is that the average time spent in orbiting at a fire is equal over all fires for all air tankers, considering the high

VARIATION OF THIS FACTOR. IF ORBITING TIME CAN ACTUALLY BE MEASURED FOR A SERIES OF FIRES FOR INDIVIDUAL AIR TANKER TYPES, IT COULD EASILY BE INSERTED INTO THE FORMULA.

IGNORED IS THE MANEUVERABILITY OF DIFFERENT AIR TANKER TYPES UNDER DIFFERENT TERRAIN AND WIND CONDITIONS. THIS FACTOR IS IMPORTANT, HOWEVER, ONLY ON A RELATIVELY SMALL PERCENT OF THE TOTAL NUMBER OF DROPS MADE BY AIR TANKERS ON FIRES, AS NOTED IN A STUDY OF SEVERAL THOUSAND FEET OF MOTION PICTURE FILM OF AIR TANKER OPERATIONS.

UNTIL SUCH TIME AS THESE ASSUMPTIONS BECOME FACT THE USER OF THE FORMULA MAY WISH TO APPLY A CORRECTION FACTOR TO THE INDEX BASED UPON HIS BEST ESTIMATE OF THE COMPARATIVE EFFECTIVENESS OF INDIVIDUAL AIR TANKERS.

2. V = VOLUME OF TANK, IN GALLONS. ASSUME A CONSTANT LOAD EACH TRIP OR USE THE TOTAL OF ACTUAL LOAD VOLUMES.

3. N = NUMBER OF TRIPS MADE TO ONE FIRE OVER A CONSTANT DISTANCE (D) FROM AIRPORT TO FIRE, AND RETURN, ON A SUSTAINED OPERATION.

4. D = DISTANCE TO FIRE FROM AIRPORT, IN MILES. THIS FACTOR IS CONVERTED TO TOTAL ROUND TRIP DISTANCE BY USING A MULTIPLIER OF "2" (INCLUDED AS PART OF THE CONVERSION FACTOR "120"). THIS PORTION OF THE CONVERSION FACTOR COULD BE ELIMINATED BY MAKING D EQUAL TO ROUND TRIP DISTANCE. PILOTS AND AIR OPERATIONS PEOPLE ARE FAMILIAR WITH USING THE ONE-WAY DISTANCE TERM, AND IT IS SUGGESTED THAT THE ROUND-TRIP DISTANCE FIGURE COULD OCCASIONALLY CAUSE SOME CONFUSION.

IT IS ASSUMED THAT THE PLANES FLY IN A STRAIGHT LINE DISTANCE FROM THE AIRPORT TO THE FIRE. THIS ASSUMPTION IS NOT ALWAYS CORRECT AND WILL VARY DEPENDING ON THE TERRAIN (PILOTS MAY TAKE DEVIOUS ROUTES TO AVOID CLIMBING OVER HIGH MOUNTAINS OR FLYING NEAR AREAS OF TURBULENT AIR, ETC.) AND ON THE POWER OF THE AIRCRAFT (SOME AIRCRAFT CAN CLIMB FASTER THAN OTHERS AND THEREBY SELECT A MORE DIRECT ROUTE TO A FIRE WHEN NECESSARY). SINCE THESE FACTORS ARE QUITE VARIABLE AND ONLY OCCASIONALLY CONTRIBUTE TO THE TIME REQUIRED FOR AN INDIVIDUAL AIR TANKER TO REACH A FIRE, THEY ARE IGNORED IN THE FORMULA.

5. R = RATE OF SPEED OF AIR TANKER IN MILES PER HOUR. THE CONVERSION FACTOR OF 120 INCLUDES A FACTOR OF "60" WHICH CONVERTS TIME FROM HOURS TO MINUTES, RESULTING IN A MORE HANDY FIGURE FOR THE CAPABILITY INDEX.

R CAN BE ASSUMED FROM EXPERIENCE OR KNOWLEDGE OR CAN BE ACTUALLY CALCULATED OVER A SERIES OF SEVERAL OPERATIONS FOR ANY GIVEN AIR TANKER. IT IS CALCULATED BY MEASURING THE DISTANCE (D) TO THE FIRE, MULTIPLYING BY TWO, AND DIVIDING BY THE TIME ACTUALLY REQUIRED BY THE AIR TANKER TO MAKE THE FLIGHT TO AND FROM THE FIRE. TIME REQUIRED FOR TAKEOFF, AVOIDING TOPOGRAPHIC OBSTACLES EN ROUTE TO AND FROM THE FIRE, ORBITING AT THE FIRE, AND LANDING WOULD BE INCLUDED IN THE OVERALL AVERAGE FIGURE AND WOULD TEND TO DECREASE THE OVERALL AVERAGE FOR THOSE AIRCRAFT REQUIRING A SHORT TAKEOFF AND LANDING DISTANCE AND THOSE ABLE TO MANEUVER IN TIGHTER PLACES AT THE SCENE OF A FIRE.

6. T = Average down-time at the airport between trips on a sustained operation, in minutes. This figure will be relatively small for air tankers with low capacities requiring short refill times and will be relatively large for larger capacity air tankers requiring longer refill times. On a sustained operation it will also reflect the average time required for servicing and maintenance.

   Down-time is best estimated by actually measuring the down-times for individual air tankers over a series of sustained operations on forest fires and taking the average. The average down-time (T) is multiplied by (N-1) to give the total down-time between trips on any one fire.

   Down-time will tend to become equal for all air tanker types as facilities become adequate at all locations for the handling of the maximum size air tanker.

7. The term VN measures the total gallons delivered by an air tanker on a fire.

8. The term $\frac{120\ ND}{R}$ measures the total time in minutes required for flight in the air.

9. The term T (N-1) measures the total time in minutes required for loading, servicing, maintenance, etc., between flight trips to the fire.

Using this formula and the average figures in Table 2, page 20, the theoretical capabilities of the four air tanker types used in the Division's 1959 experiment were calculated and are shown in Table 4. These figures show that the larger, faster air tanker types had an increasing relative advantage over the smaller, slower tankers as distance to the fire increased, but that the smaller, slower tankers had an increasing relative advantage as the number of trips to the fire increased up to a limit of about six trips.

These results came about largely because of the differences in average down-time. The longer down-times for larger air tanker types were partly due to the admittedly inadequate loading facilities at some of the Division's air bases. Future budgeting should correct these inadequacies.

Although Table 4 shows only N = 2, 6, 10, and 14, calculations were made also for N = 4, 8, and 12, but the latter figures were deleted from this report for brevity. Figures 10 to 12 show the relationship of the Capability Indexes in graphic form

Table 5 shows the comparison of contract rates paid for the services of the different air tanker types in 1959 by the Division of Forestry. The ratios can be compared to the Capability Index ratios in Table 5, but again the relationship MUST BE TEMPERED by consideration of the data used and the assumptions made in calculation of the Capability Indexes.

Table 5. Comparison of contract rates of air tankers used by Division of Forestry in 1959.

	Cost/hr (dollars)	Ratio of Cost/hr to ...		
		N3N	Twin Beech	TBM
N3N	95	-	-	-
Twin Beech	120	1.26	-	-
TBM	225	2.37	1.88	-
F7F	350	3.68	2.92	1.56

TABLE 4. CAPABILITY INDEXES OF AIR TANKERS USED ON DIVISION OF FORESTRY FIRES IN 1959

10 MILES

N= \ D=	N3N	Twin Beech		TBM			F7F			
			Ratio to		Ratio to			Ratio to		
	C.I.	C.I.	N3N	C.I.	N3N	Tw.Bch.	C.I.	N3N	Tw.Bch.	TBM
2	12.2	23.0	1.89	42.9	3.52	1.87	56.5	4.63	2.46	1.32
6	10.9	18.7	1.72	33.3	3.06	1.78	41.7	3.83	2.23	1.25
10	10.7	18.0	1.68	31.9	2.98	1.77	39.7	3.71	2.21	1.24
14	10.6	17.7	1.67	31.3	2.96	1.76	38.9	3.67	2.18	1.24

20 MILES

N= \ D=	N3N	Twin Beech		TBM			F7F			
			Ratio to		Ratio to			Ratio to		
	C.I.	C.I.	N3N	C.I.	N3N	Tw.Bch.	C.I.	N3N	Tw.Bch.	TBM
2	6.7	13.9	2.07	27.3	4.07	1.96	38.4	5.73	2.76	1.41
6	6.3	12.2	1.94	23.1	3.67	1.89	31.0	4.92	2.54	1.34
10	6.2	11.9	1.91	22.4	3.60	1.88	29.8	4.80	2.50	1.33
14	6.2	11.8	1.90	22.1	3.56	1.87	29.3	4.72	2.48	1.32

30 MILES

N= \ D=	N3N	Twin Beech		TBM			F7F			
			Ratio to		Ratio to			Ratio to		
	C.I.	C.I.	N3N	C.I.	N3N	Tw.Bch.	C.I.	N3N	Tw.Bch.	TBM
2	4.7	9.9	2.11	20.0	4.45	2.02	29.1	6.19	2.94	1.46
6	4.4	9.0	2.04	17.6	4.00	1.96	24.6	5.59	2.73	1.40
10	4.4	8.9	2.02	17.2	3.91	1.94	23.9	5.43	2.69	1.39
14	4.4	8.8	2.00	17.1	3.88	1.94	23.6	5.35	2.68	1.38

CONCLUSIONS REACHED FROM A STUDY OF TABLE 4 AND FIGURES 8 THROUGH 10, BASED UPON THE 1959 DATA, ARE AS FOLLOWS:

(1) WITH DISTANCE TO THE FIRE (D) CONSTANT, AN INCREASING NUMBER OF TRIPS (N) FAVORS THE SMALLER, SLOWER TANKERS UP TO CERTAIN LIMITS BEYOND WHICH THE RATIO OF CAPABILITY OF THE TWO BROAD CLASSES OF TANKERS BECOMES ALMOST CONSTANT. FOR EXAMPLE THE RATIO OF ALL OTHER TANKERS TO THE N3N FAVORS THE N3N UP TO 6-8 TRIPS AFTER WHICH THE RATIO BECOMES ALMOST CONSTANT; THE RATIOS OF THE F7F AND TBM TO THE C-45 FAVOR THE C-45 UP TO ABOUT FOUR TRIPS; THE RATIO OF THE F7F TO THE TBM FAVORS THE TBM UP TO 2-4 TRIPS.

(2) WITH NUMBER OF TRIPS TO THE FIRE (N) CONSTANT, INCREASING DISTANCE TO THE FIRE (D) FAVORS THE LARGER, FASTER TANKERS.

EXAMPLES OF HOW THE INDEXES IN TABLE 4 WERE CALCULATED ARE AS FOLLOWS:

EXAMPLE #1:

$$C.I. = \frac{V_N}{\left[\frac{120\ ND}{R}\right] + \left[T\ (N-1)\right]}$$

N3N	F7F
LET V = 200	800
N = 4	4
D = 20	20
R = 90	180
T = 6	15

$$C.I. = \frac{200 \times 4}{\left[\frac{120 \times 4 \times 20}{90}\right] + \left[6\ (4-1)\right]} = 6.4 \qquad = \frac{800 \times 4}{\left[\frac{120 \times 4 \times 20}{180}\right] + \left[15\ (4-1)\right]} = 32.6$$

$$\frac{32.6}{6.4} = 5.1$$

THEREFORE IT CAN BE ESTIMATED THAT FOR THE DATA GIVEN, THE F7F HAS A THEORETICAL CAPACITY TO DELIVER 5.1 TIMES THE GALLONAGE OF THE N3N. THIS INDEX CAN THEN BE COMPARED AGAINST THE 1959 CONTRACT RATES OF

$$\frac{F7F}{N3N} = \frac{\$350}{\$95} = 3.68$$

WHICH INDICATES THAT FOR THE DATA GIVEN, THE F7F WOULD BE PRODUCING MORE FOR ITS MONEY, KEEPING IN MIND ALL THE ASSUMPTIONS THAT HAVE BEEN MADE.

EXAMPLE #2:

N3N	F7F
LET V = 200	800
N = 6	6
D = 10	10
R = 90	180
T = 6	15

$$C.I. = \frac{200 \times 6}{\left[\frac{120 \times 6 \times 10}{90}\right] + \left[6\,(6-1)\right]} \qquad = \frac{800 \times 6}{\left[\frac{120 \times 6 \times 10}{180}\right] + \left[15\,(6-1)\right]}$$

$$= 10.9 \qquad = 41.7$$

$$\frac{41.7}{10.9} = 3.8$$

THUS FOR THE SHORTER TRIP AND MORE SUSTAINED OPERATION, THE ADVANTAGE OF THE F7F OVER THE N3N DECREASES.

* * * * * * *