NATIONAL BUREAU OF STANDARDS REPORT

5697

Requirements for Heat Resistant Aircraft Lighting Equipment

by

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NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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Report to
Equipment Laboratory
Wright Air Development Center
Department of the Air Force

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U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

Requirements for Heat Resistent Aircraft Lighting Fixtures

1. Introduction

As the speeds of aircraft approach and exceed the speed of sound, friction between the airplane surfaces and the air becomes more and more important. It has long been evident that this friction would result in temperatures which must be taken into account in designing the aircraft. The case of lighting fixtures, however, demands special consideration in view of the heat which is liberated within the fixture itself. The Wright Air Development Center, recognizing this situation, requested the National Bureau of Standards to undertake this project to determine requirements for improved fixtures to meet conditions resulting from air speeds up to Mach 3.

2. Nature of project

The project was to be a joint one in which the Bureau of Standards was to collaborate with the manufacturers which produce the various parts of the lighting units. These manufacturers were to carry on the general development work, the Bureau of Standards' functions being limited to the coordination of their programs, the testing of parts and assemblies, the standardization of parts, the preparation of specifications, and such limited development work as should be required to expedite the project. This plan has been followed and it has worked well.

3. Requirements

The target of the project has been the development of equipment suitable for use on aircraft flying at Mach 3. Consultation with aerodynamic experts established that this would correspond to an equilibrium surface temperature of about 650°K (700°F). Since there is a source of heat within each lighting unit, a temperature difference is required to transfer the heat from the lighting unit to the slip stream. Fortunately, at speeds of the order of Mach 3, the thermal conductance from the wing surface to the air becomes practically infinite. This means that it is not necessary to simulate the flow of air over the units in order to determine the temperature drop required for the transfer of heat from the unit to the air since that temperature difference practically vanishes. Such a determination would have been a rather impracticable undertaking in view of the small number and small size of the wind tunnels available in this country which are capable of developing Mach 3. In view of the impracticability of such tests and the high thermal conductance at the exterior surface of the cover glass, this surface has been treated as a critical boundary corresponding to a definite air speed and the heat distribution within the unit is considered as determined by the temperature distribution over this boundary surface. This, of course, is only an approximate relationship since the temperature distribution over the cover glass in flight will not be exactly the same as that in a heat test chamber, but it seems a reasonable approximation and the only practical approach to the testing of such lighting units in the laboratory.

4. General Procedure

As the result of a series of preliminary tests, a procedure for mounting the units in a temperature test chamber was developed. Each unit was placed in the test chamber on a sheet of transite supported on a gridwork. A baffle was used to prevent the measurements from being influenced by radiation received directly from the nearest wall of the test chamber which contained heating elements. Each unit was operated at normal voltage until it reached approximately its maximum temperature and then the temperature of the chamber was gradually increased until the unit failed or the maximum obtainable temperature was reached. Whenever the heating elements of the chamber were used, a fan was operated to make the temperature throughout the chamber more nearly uniform. During the test, the temperature at the center of the chamber was recorded by an automatic pressure type thermometer. Thermocouples were used to measure the temperatures at other locations thought to be significant. The temperature inside the cover glass was assumed to be the ambient temperature for the lamp and the temperature on the outer side of the cover glass was considered an approximation to the critical temperature to be expected on the cover glass surface during flight. In the case of the red and green units, the procedure of these tests also included measurements with a specially designed colorimeter to determine the extent of the color changes, and photometric measurements were made to determine the loss of candlepower at the higher temperatures.

5. Present Equipment

Since the limitations of present designs with respect to ambient temperature were not known, the first phase of the project was directed towards testing the current types of units to determine the highest temperatures at which these lighting units can be used and which parts of the units will fail first. Those tested included several wingtip lights, tail lights, fuselage lights, and one landing light. They are described in Table I.

The results of these tests, with the exception of those for the landing light, are summarized in two tables. Table II shows the temperatures* which were measured at the different locations, the changes in chromaticity, and the loss in intensity, presumably caused by loss in transmittance of the cover. In addition to the measurable effects, a number of qualitative

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*In this report temperatures are generally given in the absolute system (°K) and in the Fahrenheit system (°F). The latter system seems to be in use among some manufacturers. Since the temperatures with which we are concerned are remote from those at which °F have sensory meaning, there seems to be no advantage in this system for the present project. It is of interest, however, to appreciate the relative temperature intervals between the lamp filament temperature, which is regularly given in degrees Kelvin, the temperatures measured, and the 0°K corresponding to empty space. In general values are rounded to the nearest 0° or 5° as representing the degree of accuracy generally attained.

results were recorded and these are shown in Table III. Several of the lights developed appreciable blackening of the cover glass, apparently as a result of products evaporated from the gasket cement. The gasket cement was melted, softened, or charred in practically every case. The gasket materials in most cases withstood the temperatures reached for the brief period during which they were exposed, but the cork gaskets used in one type of unit charred badly. The bases of several lamps used in the position light units were corroded and in every case the solder on the center contact of the lamp fused. In several cases, solder used in the assembly of the units also gave way. The surface finishes of the metal parts were generally roughened, darkened, or cracked. In only two cases were the finishes considered satisfactory after the test.

The units listed in Table I are divided into two groups. As a result of the experience gained in testing the first group of units, it was decided that four additional units should be tested with an improved procedure. These are listed in the second group and it will be noted that the fuselage lights are of the same design as those included in the first group. In this case the units were tested at a succession of increasing temperatures. At each temperature the ambient was held practically constant until the unit reached thermal equilibrium and then the unit was allowed to cool for inspection. The room temperature was used for the first ambient and the chamber temperature increased in steps of 30°K to 40°K for the higher ambients. This procedure was continued until the chamber ambient reached 425°K. More thermocouples were used in this test so that in addition to the chamber ambient, critical temperature, and temperature inside the unit, temperatures were also measured between the cover glass and gasket, at a point within the unit close to the center contact of the lamp, and on the outside of the unit between the fixture and the mounting plate. As the critical temperature on the outside of the coverglass increased, the differences between this temperature and the temperatures of the several other locations measured remained substantially constant. The readings at ambient 85°F, however, are higher than would be expected from the other temperatures. This is because the fan was not used at this lowest temperature which approximated that of the room. The apparent anomaly in graph 2 of Figure 1b is presumably due to the absorption of a greater percentage of the radiant energy by the yellow glass than by the colorless glass, combined with a lower convection loss in its underneath position. The introduction of the forced convection within the test chamber between the recordings of the first and second sets of temperatures increased the rate at which the yellow glass transferred heat to the air in the chamber more than enough to offset the rise in the ambient.

The results in this case which are shown in the lower parts of Tables II and III were similar to those in the previous test. The lamp bases blackened and there was some blackening of the cover glasses. The gaskets were deformed by the pressure of the glasses and the solder on the lamp contacts melted.

6. Improved units

By the time the tests on the additional tail light and fuselage light units had been completed, the Grimes Mfg. Co. had been able to make available six improved wingtip position lights. The lamps used in these units had high-temperature basing cement and the solder on their bases was an alloy with a higher melting point than that used on the usual production lamps. These units were also provided with silicone rubber gaskets which were expected to remain serviceable to a higher temperature than those used in units of current production.

These improved units were tested in the same manner as the last four of the current type units, on alclad sheets which in this case were suspended vertically so that the units would operate as nearly as practicable in the same manner as in service. The same measurements were made as in the case of the previous units except that no thermocouple was inserted in the socket to obtain the temperature of the center contact. Fewer temperature steps were used, the current being turned on in the lamps and the chamber at the same time and the first measurements were made when the chamber ambient was slightly over 370°K (205°F).

The results for the improved units were very similar to those obtained with the best current model units except that the failure temperatures were higher. At the maximum temperature, when the chamber ambient was 34°K (60°F) higher than that on the test of the current type unit, the solder on the lamp contacts fused, the gaskets hardened and became deformed, and also a new difficulty developed; the protective coating on the backs of the reflector surfaces on the lamps blistered. This blistering was sufficient to indicate that some other method of making or protecting reflectors on the lamps will be necessary. No difficulty was experienced with the fusion of the solder with which the units were assembled, or the finish used on the improved units.

7. Temperature of critical parts

Some of the tests which have been made have provided temperature values measured at different locations nearly simultaneously. From these values it is possible to find the temperature differences between the locations at which the measurements were made. These temperatures are available for the tail lights and fuselage lights which make up the second group of current type units tested, and for the wingtip light of improved construction. They are plotted in the graphs of Figures 1 to 3. The corresponding temperature differences, with the exception of those cases in which the fan was not operating, are shown in Figures 4 to 6. It may be seen from the latter figures that the temperature differences tend to be independent of the ambient temperature once equilibrium is reached with the lamp incandescing. There are two exceptions and there is a slight tendency for the temperature differences to diminish with increasing cover glass temperature, which should be expected since, if it were possible for the critical temperature to approach the filament temperature, the differences would approach zero. These temperature differences are believed to provide a basis for estimating

the temperatures that must be withstood by critical parts in order to make the unit satisfactory for use at a given surface temperature.

8. Developments in progress

8.1 Gaskets. While other parts will need improvement to provide a unit that will operate reliably at the target temperature, the immediate limitations are all imposed by the gaskets and lamps. The General Electric Company has been experimenting with different compositions in an effort to produce a silicone-rubber gasket that will stand the maximum temperature for which such gaskets can be used. We have tested six types of silicone gaskets. The results are still far below the temperatures required for lighting units operating at the target temperature and the General Electric Company is continuing its work in search for further improvement. The gaskets now available, however, justify the expectation that it will be practicable to design a unit for intermediate temperatures which can be equipped with these gaskets. The results of the gasket tests are shown in Tables IV, V, VI, and VII.

For units to operate at higher temperatures it will probably be necessary to use a design which does not require as soft a gasket as the silicone rubber ones which we have been testing. It seems probable that a much harder gasket could be used if the metal, glass and gasket surfaces which make contact were sufficiently smooth and true to enable the cover glass to seat continuously on the gasket without having to compress the high spots of the gasket surface more than a few thousandths of an inch. In order to verify this principle, a series of tests might be made with units under various heads of water held back by different types of gaskets and clamping surfaces of different degrees of smoothness. In this way it should be possible to find out if surface accuracy can take the place of resiliency at high temperatures.

8.2 Lamps. As indicated above, two serious limitations have been found in the experimental high temperature lamps thus far tested; the reflector backings have blistered and the solder on the center contact has fused at the test temperatures. It is believed that it should not be difficult to find a solder or brazing material of sufficiently high fusing point and resistance to oxidation to make a satisfactory center contact. It is also possible that the center contact could be welded. Some experiments have been made at this Bureau with silver solder but the lamps on which the silver solder was used had been originally soldered with a softer material the removal of which may have weakened the lamps and caused them to have shorter lives than would be expected from new lamps with silver solder contacts. There is no reason to doubt that the lamp manufacturers will be able to supply lamps with center contacts that are sufficiently resistant to fusing for use in the intermediate type assemblies.

The backing materials used to protect the silvered area of the GG type of position-light lamps contain an organic vehicle and the blistering is presumed to be due to the evaporation of gases from this material. If some

of this gas is released between the backing and the metal layer on the glass blistering is to be expected. It was believed that lamps which were subject to this blistering would not be considered satisfactory for service because the backing material is liable to be completely detached from the lamp wherever blistering occurs. In search of a means of overcoming this difficulty, the Lancaster Glass Co. prepared a lot of 10 special lamps consisting of five pairs each representing a different process. These are listed in Table VIII together with a description of the results for the two lamps of each type after testing for at least 7 hours at 590°K (600°F). The first process listed is that used for lamps in regular production. These lamps were taken from those previously furnished. The second process, in which a flash plating of copper was used, was suggested by the observation that a narrow band about the base of the usual production lamps retained its bright appearance far better than the rest of the reflector surface after the heat tests. The only difference which could be discovered between this part of the reflector surface and the remainder was that this part received only a very thin flash of copper plating. The two samples representing this process were an attempt to treat the entire reflecting surface in a manner corresponding to the normal processing of this bottom band. On the remaining samples no copper was used since the results with the regular lamps indicated that copper had migrated through the silver in some instances and this had caused a considerable darkening of the reflector surface.

An examination of the results recorded in Table VIII shows that these lamps were very unsatisfactory. None of the reflector surfaces withstood the heat on the whole any better than the usual production type of silvered surface, although the causes of failure were different. This led to the consideration of other methods. Since satisfactory sealed-reflector lamps are regularly made with aluminum reflectors evaporated onto the glass surface, it was decided to try such lamps for this application. As the Lancaster Glass Company, which regularly silvers the bulbs used for these lamps, has not been using the evaporation process lately, it was decided to aluminize some lamps at this Bureau in order to expedite the work. The first experiments were made with two lamps from which the backing and silvering were removed and replaced by aluminum evaporated directly on to the exterior of the lamp. The results obtained were very encouraging.

As a result of these experiments, additional sample lamps were sent to this Bureau to enable us to make further tests. These new lamps are not of the same design as the ones used for the previous tests. They are lamps made for use in warning lights but they have the same wattage and approximately the same bulb size as the GG lamps used in wingtip lights. They were presumed to have high melting point solder and basing cement, but the results indicate that the bases are not as satisfactory as those on the lamps used for the tests described in Table VIII. The silver has been removed from these lamps and aluminum evaporated onto the surface of 14 of them. Attempts to make heat tests on their reflector surfaces have been unsatisfactory because many of them have blackened or developed air leaks or open circuits in their bases. Some of these failures have occurred after only two hours of operation at the test temperature. The results are summarized in Table IX.

In no case have any of the aluminized lamps shown any deterioration of the aluminum surface, but in most cases the aluminum is not as complete a reflector as is desired. This is shown by the fact that when the filament incandesced it was visible through the reflecting surface and some unaluminized pores within the reflector area also became visible. It seems likely that these difficulties can be overcome by more thorough cleaning of the bulb surfaces and by evaporating a thicker layer of aluminum onto the lamps. The aluminum is showing good adhesion. Apparently it is not affected by handling, and attempts to remove it by applying adhesive tape to the back surface of the reflector and later removing the tape seem to have had no effect on the aluminum.

While these experiments were going forward at this Bureau, the Lancaster Glass Co. was preparing two additional lots of sample lamps. One of these was a further attempt to make a satisfactory reflector with silver and a flash of copper plate. The other was made by a process similar to their usual process but the spray coat was a new compound of greater heat resistance than the coat used on the production lamps. When these samples were received they were given heat tests similar to those made on the other samples and the results are given in Table X. The flashed copper reflectors had the same defects as the two tested in the first lot (Table VIII). The new spray coat appears very promising.

In addition to the difficulties experienced with the center contacts and the reflector surfaces, there is another limitation on the use of incandescent lamps in high ambients. This is known as the water cycle. It is a chemical cycle which starts with the small residue of water vapor remaining within the lamp bulb. When this water vapor comes into contact with the incandescent filament, it loses its oxygen to the tungsten. The resultant tungsten oxide is a gas at this temperature and drifts through diffusion to the inside surface of the bulb. The temperature at this surface is much lower than that at the filament which allows the tungsten oxide to adhere to the glass surface. Meanwhile the hydrogen released by the formation of the oxide at the filament surface has also been diffusing through the gas of the lamp and also reaches the bulb wall. At the temperature of the wall, the hydrogen takes the oxygen away from the tungsten oxide, leaving the metallic tungsten as a black deposit on the inside surface of the bulb while the oxidized hydrogen returns to the filament as a molecule of water vapor and starts the cycle again. The General Electric Co. is at work on a solution of this problem and encouraging results are reported.

The water cycle both shortens the life and reduces the luminous intensity of the lamps. The black tungsten deposit left on the bulb soon becomes thick enough to absorb a considerable part of the light which otherwise would be radiated in needed directions. This absorption also raises the temperature of the bulb which is equivalent to operating the lamp in a higher ambient. On the other hand, the loss of tungsten from the filament reduces the cross-section of the filament and does it quite unevenly. This causes the temperature of the filament to rise at the locations where the cross-section has been most reduced. This rise in

temperature increases the oxidation of the filament at these locations and soon the filament reaches the melting point at one of the hot spots.

9. Parts for intermediate type equipment

Unless some means of eliminating the water cycle is found, the temperature at which it shortens lamp life to the minimum acceptable for position lights constitutes a natural limit for an intermediate temperature design. The lamp engineers state that about 590°K (600°F) is the maximum ambient for lamps at which an acceptable life can be assured. This governs the temperature inside the cover glass. According to the graphs of Figures 3 and 6 the temperature inside the cover glass may reach 590°K when the outside critical temperature is only 430°K, or the inside temperature may not reach this 590° limit until the critical temperature reaches 520°K. The wide difference between these values reflects the fact that the temperature varies greatly from point to point both within and on the outer surface of the cover glass. These graphs also give 455°K and 550°K as the gasket temperatures to be expected with these critical temperatures.

The results obtained with the lamps with the improved spray coat furnished by the Lancaster Glass Co. (Table X) indicate that this backing will be satisfactory on lamps operating in an ambient of 590°K. Since only one lot of these lamps has been tested, it seems desirable to point out that should later experience reveal that this spray coat does not withstand the temperatures involved, the aluminized reflectors have an excellent prospect of doing so.

The only measurements made to indicate the temperature near the center contact of the lamp were those shown in Figures 1a, 1b, 2a, and 2b. These all indicate that the temperature at this location may be expected to run at least a little lower than at the gasket. No reason is known to believe that this relationship does not also hold for the wingtip light. An examination of a table of melting points for alloys indicates that there are several alloys commonly used for joining metals which have melting points that afford a comfortable margin above the required 550°K (275°C). The basing cement used on some of the GG type lamps furnished for testing reflector backings has shown no evidence of failing even when the lamps were being operated in an ambient of 645°K (700°F) (Tables IX and X). This warrants the expectation that this basing cement will be satisfactory on lamps used in intermediate type equipment. It is our conclusion that lamps can now be made in which all parts will withstand temperatures up to that at which the water cycle makes the lamp life inadequate for dependable service.

An examination of the information in Tables V, VI, and VII indicates that silicone gaskets of any of the compositions tested could probably be used in the intermediate type equipment. As may be seen from Table VII the red compound is definitely less desirable than the black and the white compounds. Of these the black shows slightly less increase in hardness and loss of weight than the white. Unfortunately, we do not have the same

type of quantitative values for the other compositions. Table VI contains the results of a comparative test in which four types of gaskets were given the same exposure. On the qualitative basis afforded by this table, the Deep Blue composition should give the least difficulty with clouding the cover glasses up to the temperatures for which the intermediate type equipment can be designed. Unfortunately, Table V does not confirm this indication. The tests of Table V, however, may have been on a less uniform basis than those of Table VI. A more quantitative comparison on a larger number of specimens would be necessary to select with assurance the best of these four compounds.

The improved wingtip light units furnished by the Grimes Manufacturing Co. developed no defects other than those of the lamps and gaskets when they were tested at ambients corresponding to critical temperatures well above the 520°K which has been estimated to be the maximum for the intermediate type units. These units contain sockets built with insulating materials and metallic springs which have given no indication of weakness on these tests. The parts are assembled with high temperature solder which has not softened and the finishes used have shown no sign of deterioration. We have therefore felt warranted in preparing a specification for intermediate type units.

10. Conclusions

The development has not culminated in designs for exterior aircraft lights suited for use at the target temperature of 700°F (645°K). The project is being discontinued, however, because of exhaustion of funds and the expiration of the contract period rather than because of technical limitations.

Although the cooperating lamp manufacturer has not as yet been able to supply conventional lamps that can be used in ambients above 590°K, we have received several sample lamps in quartz bulbs that offer good probabilities of lifting the ambient limit materially. The construction of these lamps is such that they cannot be used in lighting units of present design. They do not, therefore, qualify for the intermediate type units, but in properly designed units they may be suitable for use on higher speed aircraft. Should these quartz lamps prove inadequate, there may be the possibility of designing a high intensity gaseous-discharge lamp that can be operated at the required temperatures.

Metals and insulating materials are known which can be used at the temperatures required for the units operating at the target temperature. The glass manufacturers, on the other hand, hold forth no promise of red and green glasses suitable for use at these temperatures. Unless there is an improvement in the prospects for such glasses, the most promising solution would be to resort to using flash characteristics to differentiate the different units. This would appear especially desirable if gaseous-discharge lamps are used.

The use and design of gaskets is another problem that will require further study. The intermediate type unit apparently represents about the limit of what may be expected from silicone rubber gaskets. It has been suggested above that asbestos gaskets, although harder, might be usable if the gasketed surfaces were made sufficiently flat and smooth. This possibility certainly merits testing.

For the intermediate type units the project has provided two specifications, one for lamps and the other for units, which are believed satisfactory for the procurement of equipment for use on aircraft developing wing surface temperatures up to 450°K (350°F) (based on the two tests for which inside temperatures are given in Figure 3). These specifications are identified by the titles,

> "Lamps, incandescent, aviation service, wing position light; high temperature",

> "Lights, aircraft, high temperature, general specifications for".

They are now being circulated for industry comment.

Table I

Identification of Lights Tested - Current Types

Dept. of Defense No.	Manufacturer's No.	Description			Lamps			Gaskets
		Location	Color	Type	No.	Volts	Watts	
		First Group of Units						
AN 3032-5	A 1815-G-24	Wing-tip	green	recessed	A7512-24	28	26	Rubber
AN 3032-5	A 1815-R-24	" "	red	"	"	"	"	"
AN 3033-10	A 2138-G-24	Wing-tip	green	external	1524	28	21	Rubber
AN 3033-10	A 2138-R-24	" "	red	"	"	"	"	"
AN 3122-15-24*	B 6345-2-24	Wing-tip	green	reflector	A4174	28	40	Sil. Rub.
AN 3122-15-24*	B 6345-1-24	" "	red	"	"	"	"	" "
AN 3158-4	A 5715-1-1683	Tail	white**		1683	28	32.2	Asbestos
AN 3158-5	A 5715-2-1683	"	yellow**		"	"	"	"
AN 3177-9	B 3525-23-24	Fuselage	clear		311 303	28 "	43.4 8.4	Cork
AN 3177-9	B 3525-22-24	"	frost**		311 303	" "	43.4 8.4	"
MIL-L-8210	G 5400-3	Under wing	clear	landing light	4559 Par-64	28	600	
		Second Group of Units						
AN-3158-8	A 5715-3-1683	Tail	clear-colorless		1683	28	32.2	Asbestos
AN-3158-9	A 5715-4-1683	Tail	clear-yellow		1683	28	32.2	Asbestos
AN-3177-9	B 3525-23-24	Upper fuselage	clear-colorless/opaque		311 303	28 28	43.4 8.4	Sil. Rub.
AN-3177-9	B 3525-21-24	Lower fuselage	clear-colorless		311 303	28 28	43.4 8.4	" "

** diffusing covers

* Lamp drawing, number for fixture not known.

Table II

Heat Tests on Current Models - Measurable Effects

Description of Unit				Temperatures Reached*						Color		Intensity
Number	Designed Mounting	Color	Lamp Watts	Cabinet Ambient °K #	Outside Cover °K	Inside Cover °K	Cabinet Ambient °F#	Outside Cover °F	Inside Cover °F	(y",R-U-C-S) Cold	Hot	Ratio Hot / Cold
				First Group of Units								
AN-3032	Recessed	Green	26.	425	475	560	300	390	545	Negligible		0.73
AN-3032	"	Red	26.	385	445	500	230	345	445	-0.39	-0.45	0.55
AN-3033	Wing Tip	Green	21.	430	455	555	310	360	545	Negligible		0.66
AN-3033	" "	Red	21.	430	430	535	315	315	500	-0.33	-0.44	0.55
AN-3122	Wing Tip	Green	40.	415	585	---	285	595	---	Negligible		0.83
AN-3122	" "	Red	40.	430	520	---	310	475	---	-0.33	-0.44	0.49
AN-3158	Tail	White	32.	305	490	605	85	425	625	---		--
AN-3158	"	Yellow	32.	410	495	640	275	430	690	---		--
AN-3177	Fuselage	White Diff.	52.##	460	---	540	365	---	510	---		Reduced by stain
AN-3177	"	Clear	52.##	455	515	565	355	465	555	---		Reduced by stain
				Second Group of Units								
AN-3158-8	Tail	Clear-Colorless	32.	425	465	545	300	380	525			
AN-3158-9	Tail	Clear-Yellow	32.	425	475	570	300	400	565			
AN-3177-9	Upper Fuselage	Clear-Colorless/Opaque	52.	425	485	485	305	410	415			
AN-3177-9	Lower Fuselage	Clear-Colorless	52.	425	465	480	305	375	410			

* Values expressed to nearest 5° interval

\# Automatic record from bulb at center of chamber

\## Total for two lamps

Table III

Heat Tests on Current Models - Failure of Parts

Description of Unit				Effects of Heat on Parts Listed						
			Cover	Gaskets		Lamps		Fixtures		
Number	Designed Mounting	Color	Glasses Blackening	Cement	Material	Base	Solder	Solder	Finish	Notes
AN-3032	Recessed	Green	Slight	Melted	OK #	OK	Fused	Fused	Roughened	
AN-3032	"	Red	Slight	Melted	OK #	OK	Fused	Fused	OK	
AN-3033	Wing Tip	Green	None		OK #	OK	Fused	Fused*	Roughened	*Rejoined on cooling
AN-3033	" "	Red	None	Melted	OK #	OK	Fused	Fused*	Roughened	*Rejoined on cooling
AN-3122	Wing Tip	Green	None	Softened*	OK #	OK	Fused	Fused	Roughened	*Cement loosened.
AN-3122	" "	Red	None	Softened*	OK #	OK	Fused	Fused	Roughened	*Cement loosened.
AN-3158	Tail *	White	Much	No cement	OK	Corroded	Fused	OK	Sl.Dark'd	*Tested on side.
AN-3158	" *	Yellow	Much	No cement	OK	Corroded	Fused	OK	Sl.Dark'd	*Tested on side.
AN-3177	Fuselage*	White Diff.	Slight	Charred	Charred	Corroded	Fused	Fused	OK	*Tested bases up.
AN-3177	" *	Clear	Much	Charred	Charred	Corroded	Fused	Fused	Cracked	*Tested bases up.
				Second Group of Units						
AN-3158	Tail	Clear-Colorless	Slight	No cement	OK	Blackened*	OK	OK	OK	*At 255°F,400°K.
AN-3158	Tail	Clear-Yellow	Slight	"	OK	Blackened*	OK	OK	OK	*At 255°F,400°K.
AN-3177	Upper Fuselage	Clear-Colorless/ Opaque	Slight White Coating	"	Softened*	OK	Fused	OK	OK	*At 210°F,375°K.
AN-3177	Lower Fuselage	Clear-Colorless	Slight White Coating	"	Softened*	OK	Fused	Fused	OK	*At 210°F,375°K.

#Apparently functioning but see discussion of gaskets in Section 8.1. *See Notes in last column of Table.

Note: After the completion of the above tests, the tail light and fuselage light units were incandesced continuously for 24 hours at the ambient used for the final stage of the test. For the tail lights this merely increased the blackening of the cover glasses and lamp bases. The fuselage lights, however, developed additional defects. The gasket of the clear-colorless/opaque topside unit had adhered to the cover glass and when the cover glass was forcibly removed some traces of the gasket remained on it. The clear-colorless underside unit was found to have its gasket adhering to the cover glass, but upon forcible removal from the glass, the gasket remained intact in its proper place in the unit. The solder on the socket of the larger lamp was found to have softened during the test, releasing the socket.

Table IV

Heat Effects on Gaskets in Types AN-3158 & AN-3177 Units

Test Date	Exposure °F*	°K*	Hours	Deposit on inside of unit and gasket deterioration.
				Asbestos-neoprene gaskets in tail light units.
				Clear-colorless, upper unit
1-14-57	235	385	2	No deposit
1-18-57	255	395	5	" "
2- 6-57	285	415	3	" "
2- 8-57	330	440	3	" "
2-11-57	375	465	4	Slight black deposit
2-13-57	375	465	24	More " " , no cracking.
				Clear-yellow, lower unit
1-14-57	250	395	2	No deposit
1-18-57	265	405	5	" "
2- 6-57	300	420	3	" "
2- 8-57	345	445	3	" "
2-11-57	390	470	4	Slight black deposit
2-13-57	385	470	24	More " " , no cracking.
				Light blue silicone gaskets in fuselage lights.
				Clear-colorless/opaque, upper unit
11-28-56	225	380	3.0	No deposit
11-29-56	230	385	2.5	" "
11-30-56	295	420	3.5	" " , indented by cover
12- 3-56	325	435	4.0	" " , more indentation
12- 4-56	370	460	4.5	" " , " "
12- 6-56	370	460	22.5	White deposit on lamp, more indentation
				Clear/clear, lower unit
11-28-56	210	370	3.0	No deposit
11-29-56	240	390	2.5	" "
11-30-56	290	415	3.5	" "
12- 3-56	335	440	4.0	" "
12- 4-56	370	460	4.5	" "
12- 6-56	370	460	22.5	White deposit on lamp

*Temperature was measured between gasket and glass.

Table V

Heat Effects on Gaskets in Type AN-3122 Units

Test Date	Gasket Temp. °F	°K	Hours	Deposit on inside of unit and gasket deterioration
				Deep blue silicone gaskets
2-25-57	210	375	4	No deposit
2-27-57	430	495	2	Slight deposit and indentation
2-28-57	480	525	3	More " " deep indentation
3- 1-57	535	555	3	Heavy coating on glass, gasket cracked
7- 8-57	510	540	2	No deposit
7- 8-57	545	560	2	" "
7- 9-57	690	635	4	Traces of white deposit and indentation
7-10-57	695	640	6	Slight increase in deposit and "
7-11-57	700	645	6	More deposit, indented by cover, cracked
				Gray silicone gaskets
4-24-57	515	540	4.5	Light coat of white deposit
7-15-57	665	625	6	Slight trace of white deposit
7-16-57	665	625	6.5	No increase in white deposit
7-17-57	665	625	7	Slight coat of white deposit, some indentation and slight cracks, still usable.
				Black silicone gaskets *
5-16-57	580	575	6.0	No white deposit, very slight indentation
5-17-57	625	605	5.7	Slight coat of white deposit
5-21-57	560	565	6.7	White deposit not observed
5-22-57	615	595	7.0	White " " "
5-24-57	620	600	6.0	Slight traces of white deposit

* Experimental lamps were also being tested.

Table VI

Heat Tests of Gaskets Only

Date	Exposure °F	°K	Hrs.	White deposits on beaker and disintegration evident: Light Blue Gaskets	Deep Blue Gaskets	Gray Gaskets	Black Gaskets
4-29-57	390	475	4.5			None visible	None visible
4-29-57	535	555	.75			Moderate coat	None visible
4-30-57	570	575	1.0				Trace
4-30-57	660	625	.5				Moderate coat
4-30-57	715	655	3.0				Heavy coat
5-7-57	715	655	6.0				Heavy coat and disintegrated
5-9-57.	570	575	7.5				Mild coat
5-10-57	570	575	7.25				Mild coat
5-13-57	570	575	7.0				Mild coat
6-25-57	525	550	2.0	No deposit	No deposit	No deposit	No deposit
6-25-57	570	570	2.0	Slight Trace	No deposit	No deposit	No deposit
6-26-57	615	600	2.0	Trace	Slight trace	Slight trace	Slight trace
6-27-57	660	625	2.0	Trace	Trace	Trace	Trace
6-27-57	705	650	2.0	Medium coat	Mild coat	Heavy coat	Heavy coat
6-27-57	750	675	2.0	Cracked	Disintegrated	Cracket badly	Disintegrated
7-10-57	700	645	0.5	Moderate coat Cracked	Moderate coat Cracked	Moderate coat Cracked least	----

Table VII

Gasket Deterioration as Indicated by
Hardness and Weight

	Exposure		Type "A" Hardness			Weight			
Gasket No.	Temp. °F*	Hrs.	Before	After	Change	Before Grams	After Grams	Change Grams	Loss Ratio
			Small gaskets received 8-29-57						
					White Gaskets				
I	600	7.5	47	48	+1	5.639	5.285	.354	.063
II	600	7.5	47	46	-1	5.579	5.269	.310	.056
III	650	8.5	48	69	+21	5.461	4.805	.656	.120
IV	650	8.5	48	68	+20	5.467	4.873	.594	.109
V	700	8.5	50	96	+46	5.639	4.081	1.558	.276
VI	700	8.5	47	95	+48	5.525	4.098	1.427	.258
					Red Gaskets				
I	600	7.5	70	92	+22	3.579	3.320	.259	.072
II	600	7.5	70	91	+21	3.627	3.431	.196	.054
III	650	8.5	70	91	+21	3.600	3.311	.289	.080
IV	650	8.5	70	91	+21	3.722	3.495	.227	.061
V	700	8.5	70	"C"	-	3.618	-	-	-
VI	700	8.5	70	"C"	-	3.701	-	-	-
					Black Gaskets				
I	600	7.5	64	64	0	3.792	3.658	.134	.035
II	600	7.5	63	62	-1	3.860	3.742	.118	.031
III	650	8.5	64	73	+9	3.878	3.573	.305	.079
IV	650	8.5	63	72	+9	3.906	3.634	.272	.070
V	700	8.5	63	95	+32	3.905	2.625	1.280	.328
VI	700	8.5	64	96	+32	3.832	2.695	1.137	.297

"C": Crumbled *600°F=589°K; 700°F=644°K

Table VIII

Heat test on one type of regular production lamps and five types of experimental lamps representing different processes for protecting the reflecting surface.

Description of process	Description of lamps after exposure: First Test, Ambient 590°K (600°F), Duration 7.5 hours	Second Test, Ambient 590°K (600°F), Duration 7 hours
Usual silver Usual copper Usual spray coat	Spray coat blistered Silver surface good	Spray coat blistered Silver surface slightly darkened
Usual silver Flashed copper No spray coat	Outside blackened Inside tarnished in small areas	Outside blackened Inside tarnished in small areas
Double silver No copper Usual spray coat	Spray coat mostly off Silver seriously perforated and somewhat clouded	Bulb leaked Filament burned out Spray coat blistered Silver seriously clouded
Double silver No copper No spray coat	Bulb leaked Outside good Inside partly clouded	Lamp failed at start Outside good Inside somewhat clouded
Triple silver No copper Usual spray coat	Spray coat all off Silver seriously perforated and clouded	Spray coat all off Silver seriously perforated and clouded
Triple silver No copper No spray coat	Silver seriously perforated and clouded	Silver perforated and clouded

Table IX

Heat Tests on Lamps with Aluminum Reflectors

There was no evident deterioration of the reflector surface in the case of any of the lamps tested.

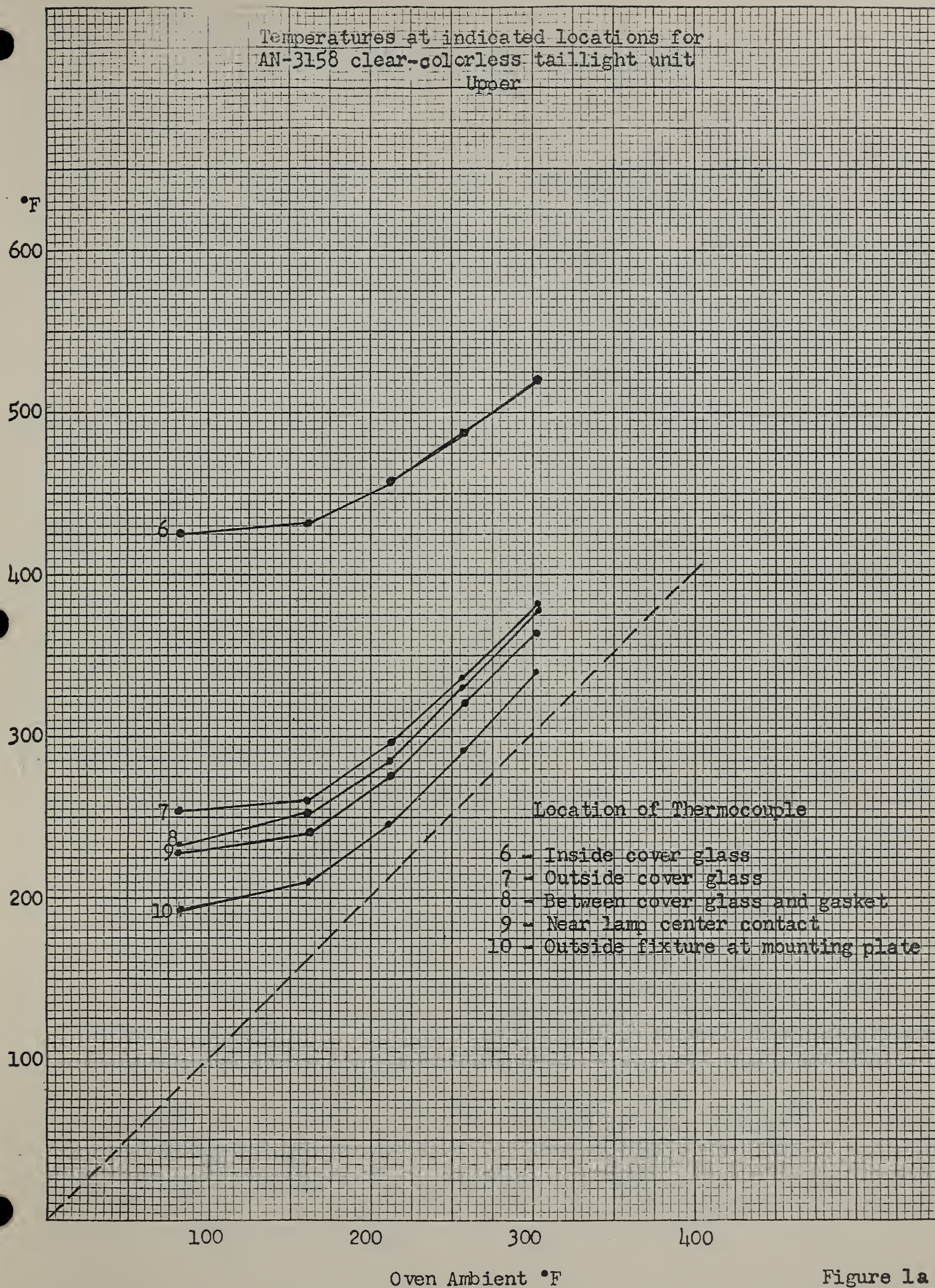
Number of Lamps Tested	Exposure			Results	
	Time	Temperature		"Life"	Condition
	Hours	°K	°F	No.-Hrs.	
	0	--	--	1 - 0	Failed after 10 minutes
2	8.	590	600	1 - 23.5	Still incandescent
	7.5	615	650		
	8.	645	700		
5	17.	645	700	2 - 4.	Failed*
				1 - 10.5	" *
				2 - 17.	Still incandescent
4	25.5	590	600	2 - 2.	Failed*
				1 - 4.	" *
				1 - 25.5	Still incandescent
5	25.5	615	650	2 - 2.5	Failed*
				1 - 8.5	" *
				2 - 25.5	Still incandescent

*Filament circuit open. Whether failure was in filament or in base was not determined.

Table X

Heat Tests on Two Experimental Types Lamps

Number of Lamps Tested	Exposure			Results
	Time	Temperature		No filament failures on these tests
	Hours	°K	°F	
	Silver Reflecting Surface and Flashed Copper Plate			
1	7.5	590	600	Reflector slight transparent
1	7.5	615	650	Reflector more "
1	7.5	645	700	Reflector intermediate between above
5	7.5	590	600	Reflectors all transparent, filaments easily and clearly visible thru reflectors when held against sky. Metal easily wiped off.
	7.5	615	650	
	7.5	645	700	
	Silver Reflecting Surface Protected by New Spray Coat			
	7.5	590	600	All lamps satisfactory
	7.5	615	650	" " "
6	7.5	645	700	2 " " 4 " some small pores found in reflectors, otherwise in good condition.
	21.5	645	700	All reflecting surfaces tarnished, porosity about the same as recorded above.



Temperatures at indicated locations for
AN-3158 clear-colorless taillight unit
Upper
°F
600
500
400
300
200
100
6
7
8
9
10
100
200
300
400
Location of Thermocouple
6 - Inside cover glass
7 - Outside cover glass
8 - Between cover glass and gasket
9 - Near lamp center contact
10 - Outside fixture at mounting plate
Oven Ambient °F

Figure 1a

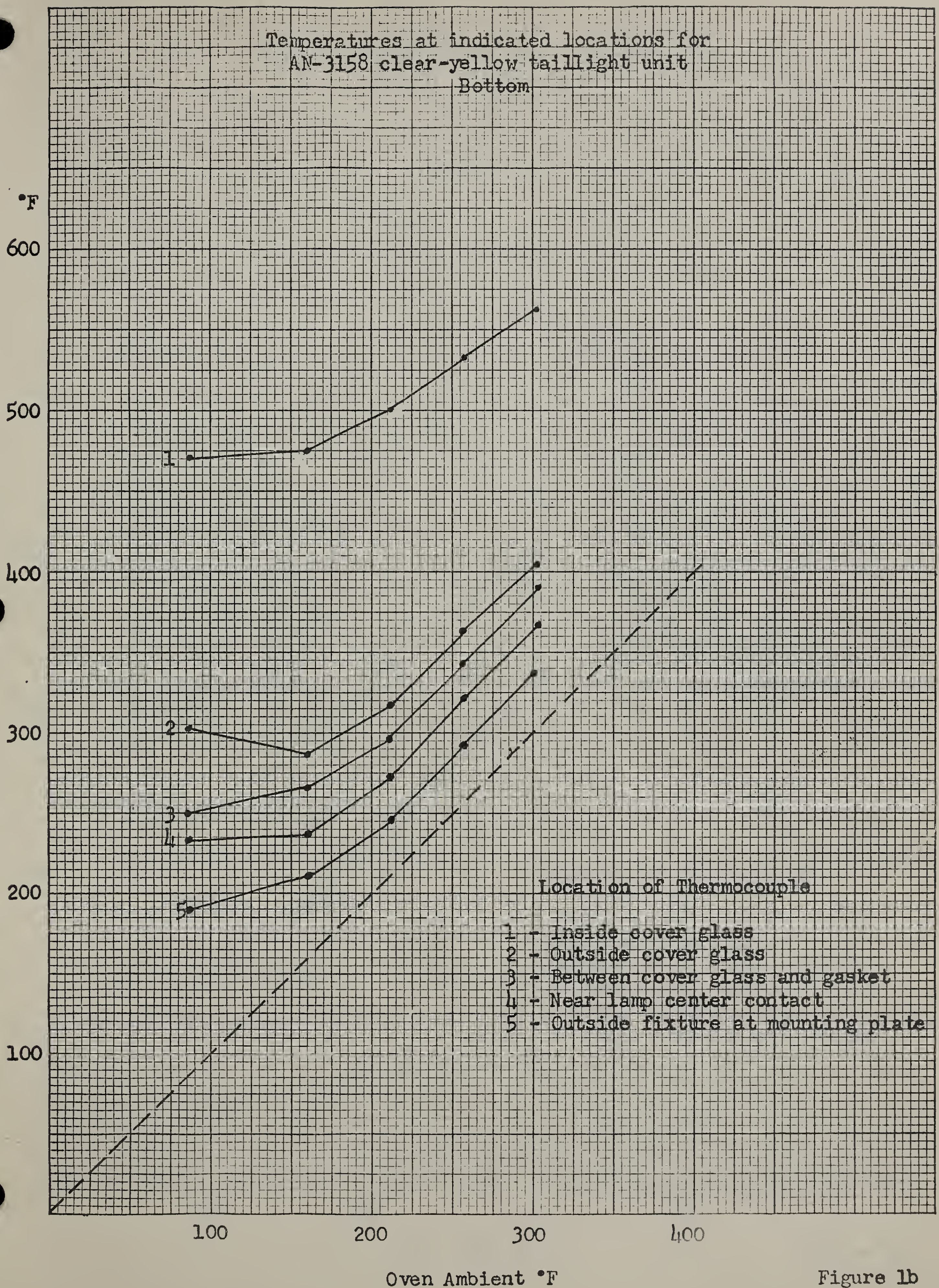

Temperatures at indicated locations for
AN-3158 clear-yellow taillight unit
Bottom
°F
600
500
400
300
200
100
1
2
3
4
5
100
200
300
400
Location of Thermocouple
1 - Inside cover glass
2 - Outside cover glass
3 - Between cover glass and gasket
4 - Near lamp center contact
5 - Outside fixture at mounting plate
Oven Ambient °F

Figure 1b

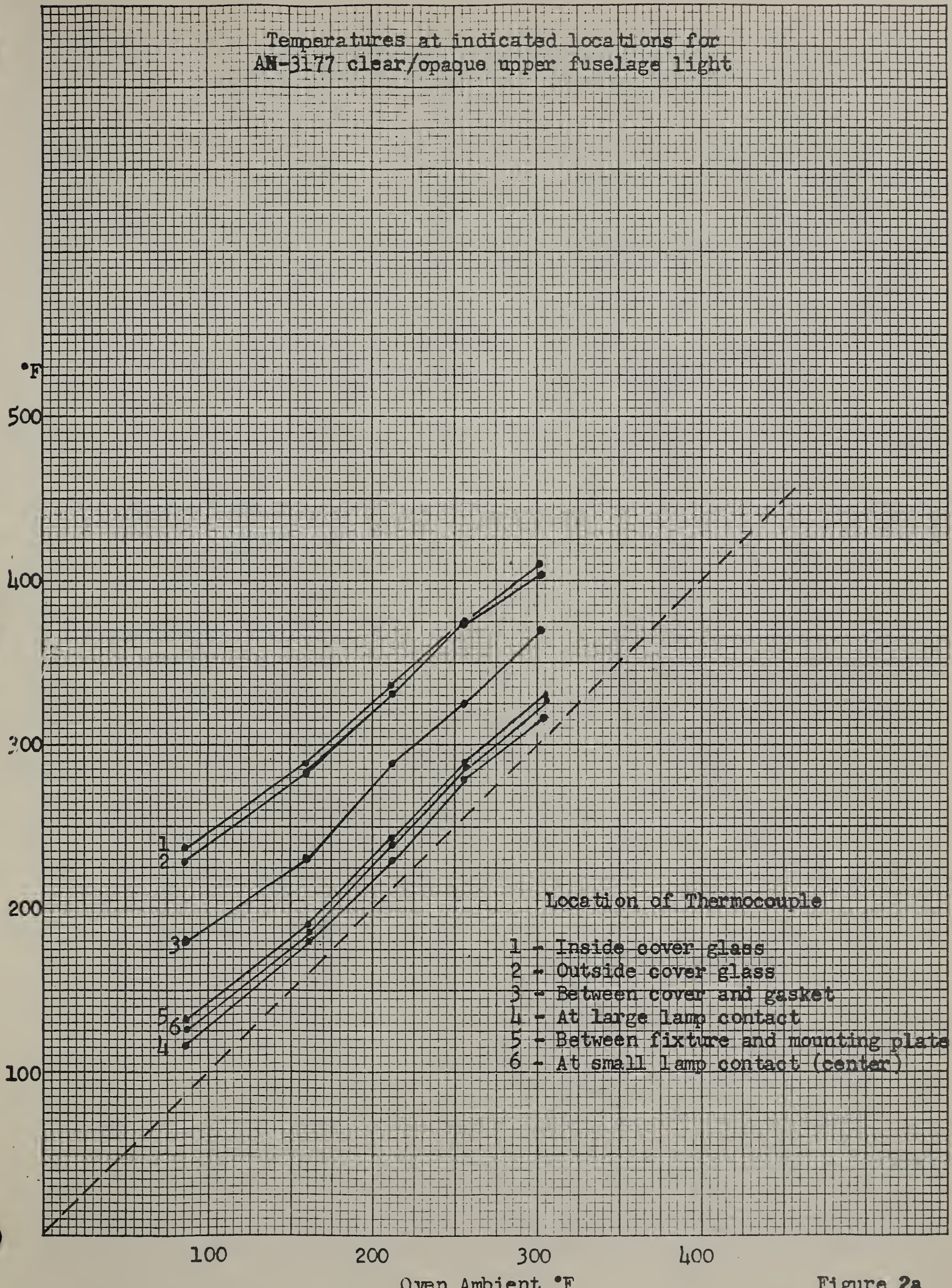

Temperatures at indicated locations for
AN-3177 clear/opaque upper fuselage light
°F
500
400
300
200
100
1
2
3
5
6
4
Location of Thermocouple
1 - Inside cover glass
2 - Outside cover glass
3 - Between cover and gasket
4 - At large lamp contact
5 - Between fixture and mounting plate
6 - At small lamp contact (center)
100
200
300
400
Oven Ambient °F

Figure 2a

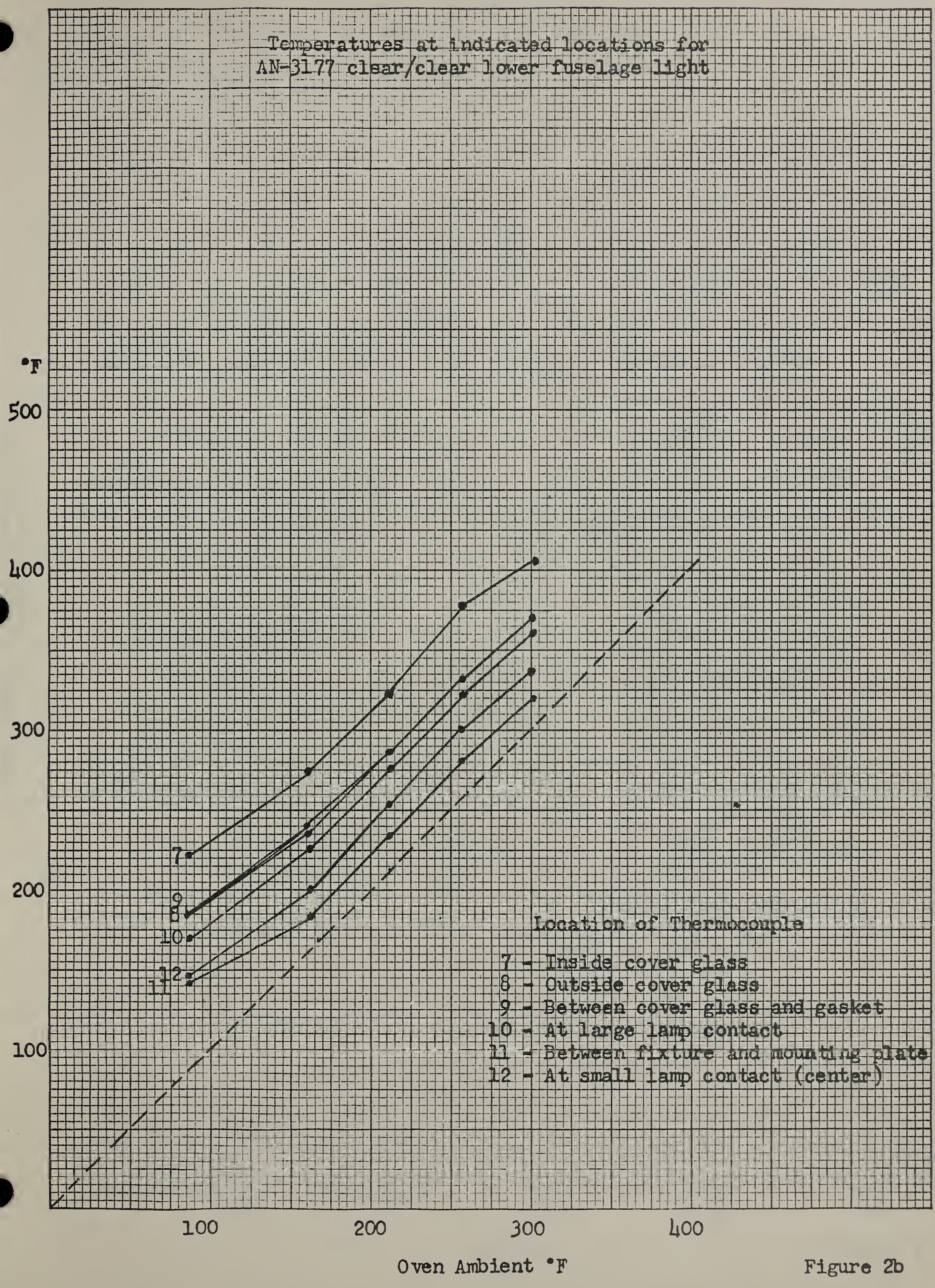
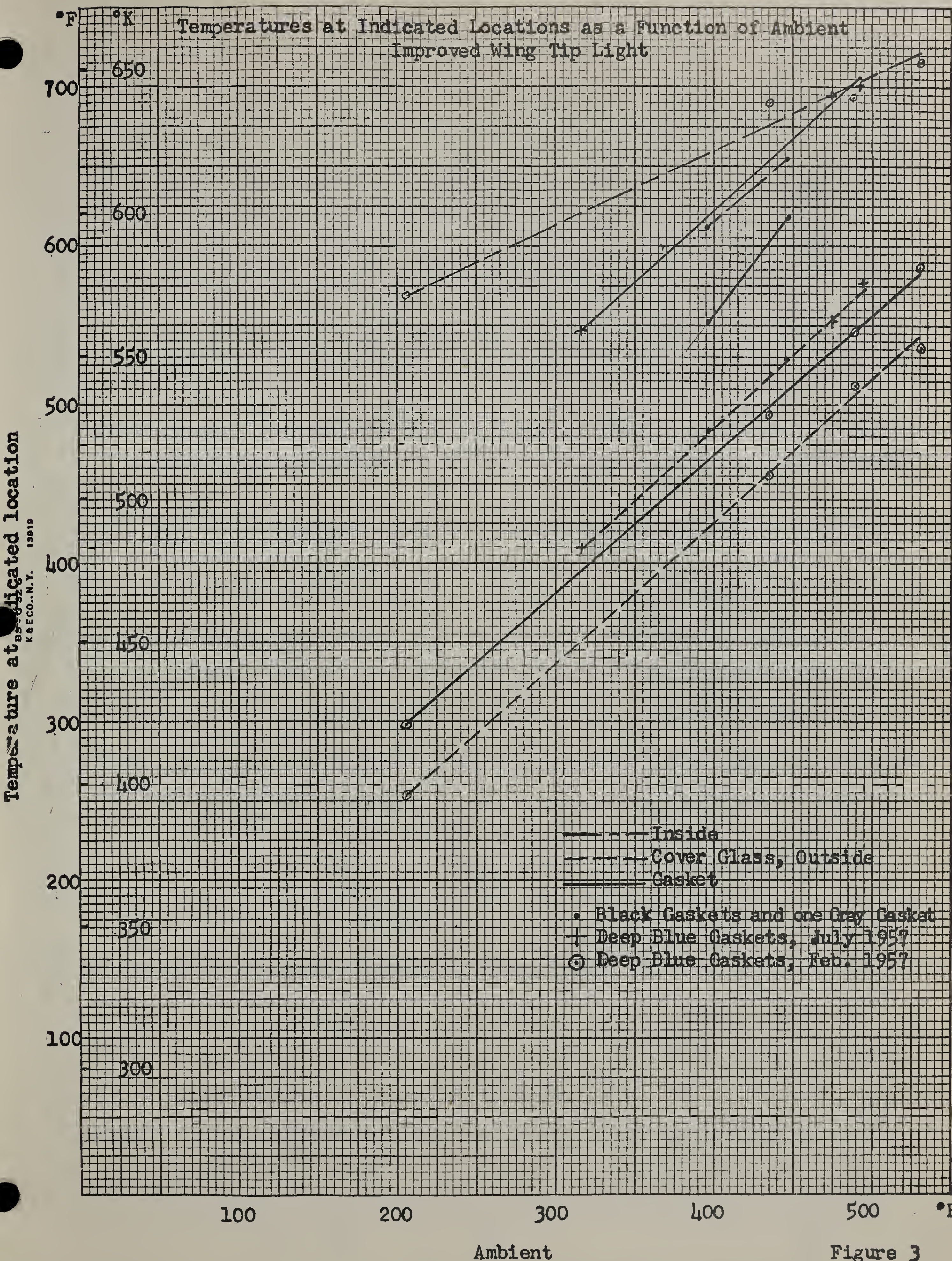

Temperatures at indicated locations for
AN-3177 clear/clear lower fuselage light
°F
500
400
300
200
100
7
9
8
10
12
11
100
200
300
400
Oven Ambient °F
Location of Thermocouple
7 - Inside cover glass
8 - Outside cover glass
9 - Between cover glass and gasket
10 - At large lamp contact
11 - Between fixture and mounting plate
12 - At small lamp contact (center)

Figure 2b



Temperatures at Indicated Locations as a Function of Ambient
Improved Wing Tip Light
°F
°K
650
600
550
500
450
400
350
300
700
600
500
400
300
200
100
Temperature at Indicated location
Inside
Cover Glass, Outside
Gasket
Black Gaskets and one Grey Gasket
Deep Blue Gaskets, July 1957
Deep Blue Gaskets, Feb. 1957
100
200
300
400
500
°F
Ambient

Figure 3

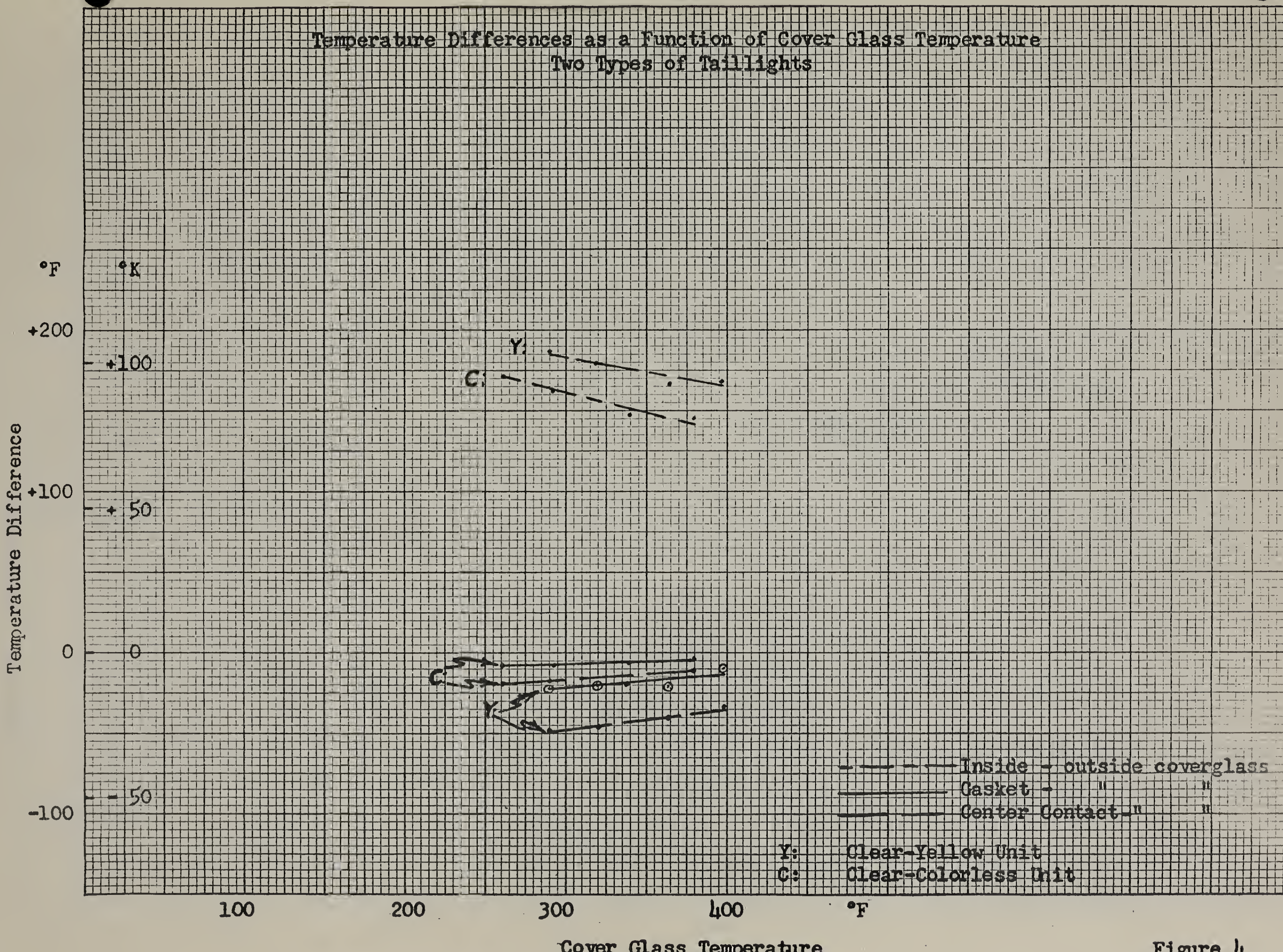
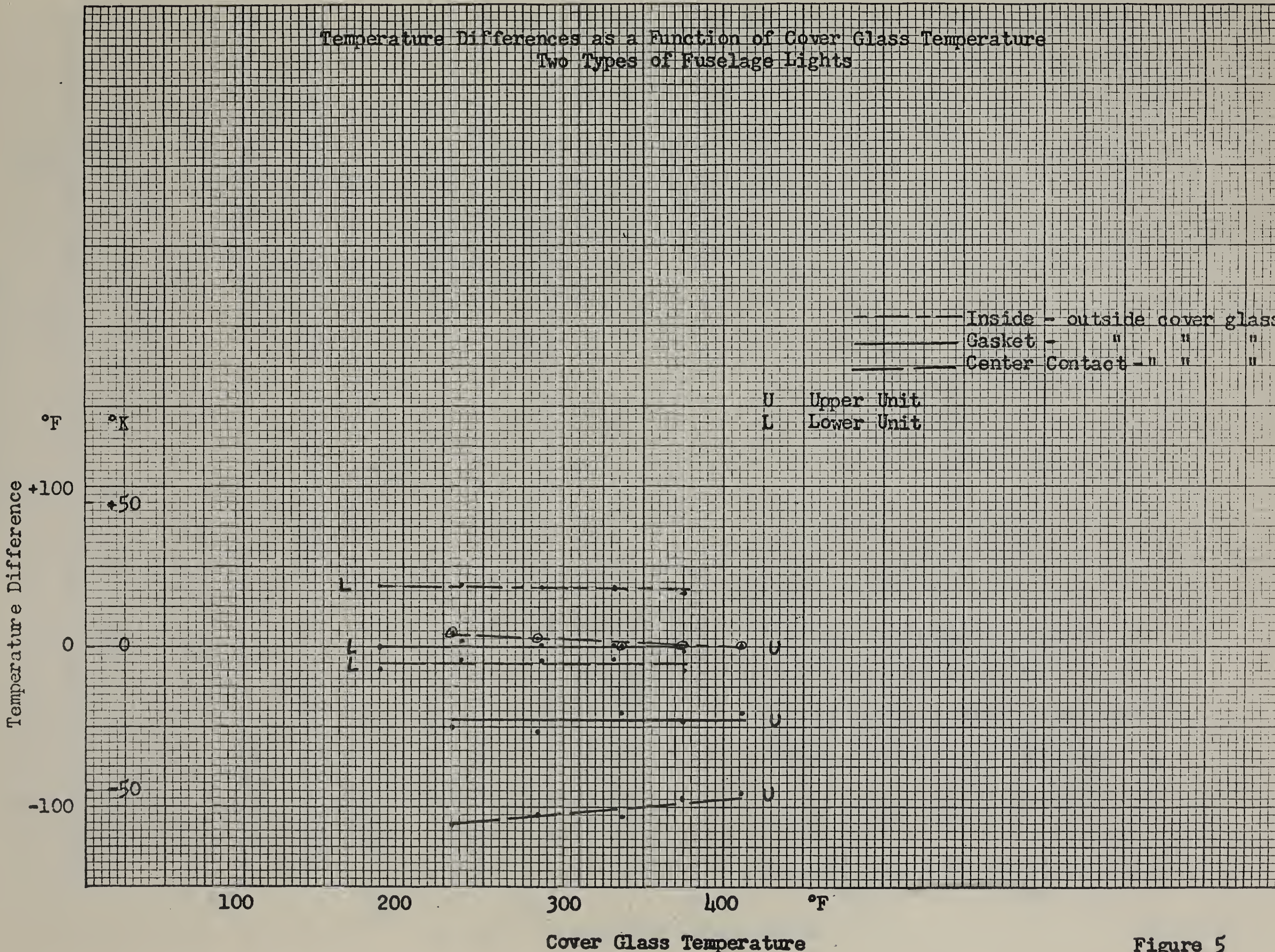
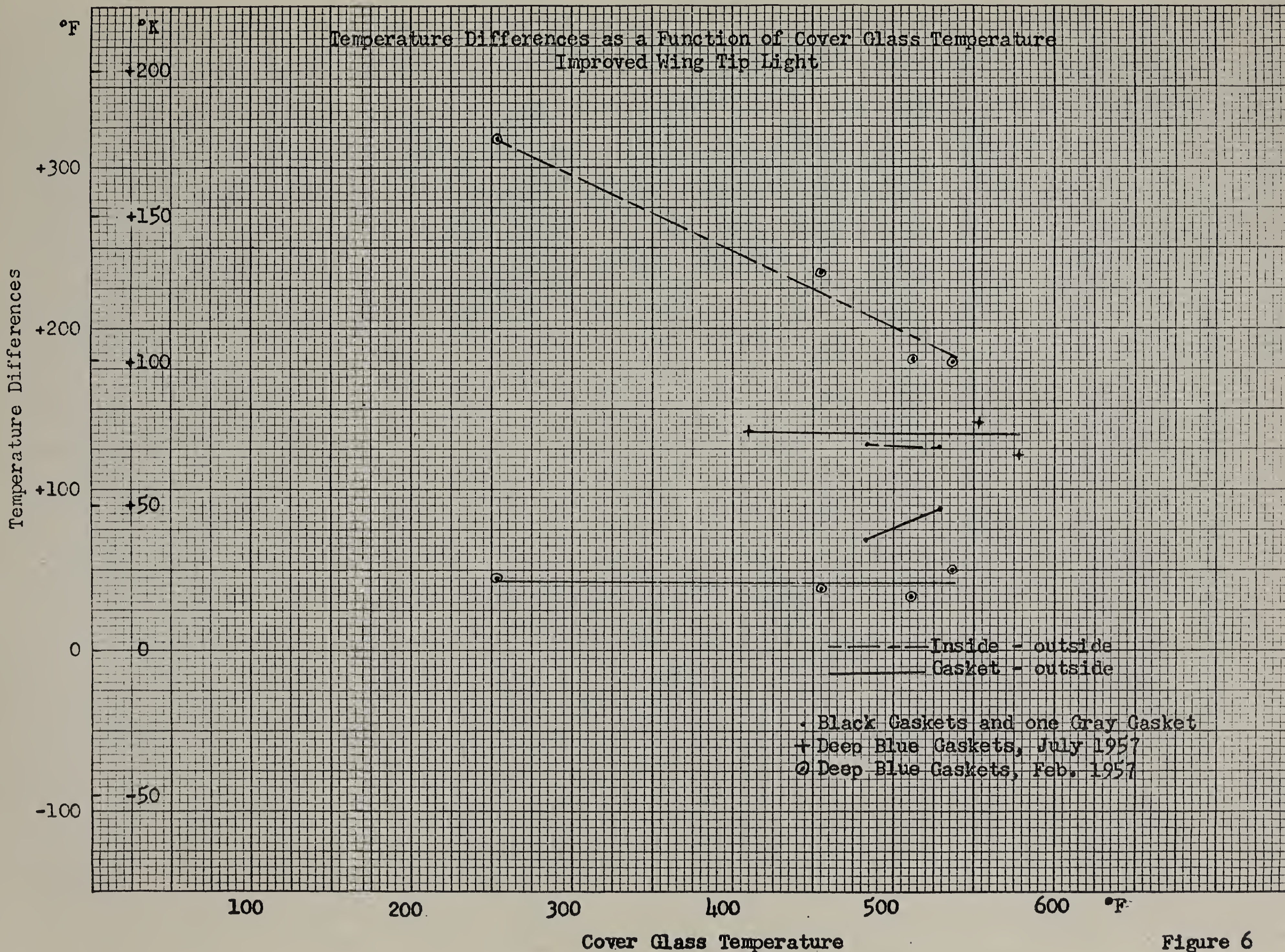

Temperature Differences as a Function of Cover Glass Temperature
Two Types of Taillights
°F
°K
+200
+100
+100
+ 50
0
0
-100
- 50
Temperature Difference
100
200
300
400
°F
Cover Glass Temperature
Y:
C:
Inside - outside coverglass
Gasket - " "
Center Contact-" "
Y: Clear-Yellow Unit
C: Clear-Colorless Unit

Figure 4



Temperature Differences as a Function of Cover Glass Temperature
Two Types of Fuselage Lights
Inside - outside cover glass
Gasket - " " "
Center Contact - " " "
U Upper Unit
L Lower Unit
°F
°K
+100
+50
0
0
-50
-100
Temperature Difference
100
200
300
400
°F
Cover Glass Temperature

Figure 5



Temperature Differences as a Function of Cover Glass Temperature
Improved Wing Tip Light
°F
°K
+300
+200
+100
0
-100
+200
+150
+100
+50
0
-50
Temperature Differences
100
200
300
400
500
600
°F
Cover Glass Temperature
Inside - outside
Gasket - outside
· Black Gaskets and one Gray Gasket
+ Deep Blue Gaskets, July 1957
⊙ Deep Blue Gaskets, Feb. 1957

Figure 6

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

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Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

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