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INTRODUCTION OF THE MODEL 190A
AIRCREW HELMET AND MBU 12/P
OXYGEN MASK INTO
CANADIAN FORCES SERVICE

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J.W. Armstrong

Defence and Civil Institute of Environmental Medicine
1133 Sheppard Avenue West
P.O. Box 2000
Downsview, Ontario
M3M 3B9

DEPARTMENT OF NATIONAL DEFENCE - CANADA

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ABSTRACT

51/ In 1982 the CF decided to adopt the Model 190 aircrew helmet and P/Q oxygen mask with wire suspension system for use by aircrew in the air combat manoeuvring (ACM) role. Numerous difficulties were encountered during their introduction into service. The resolution of these difficulties required substantial modifications to the helmet, consequently redesignated the Model 190A, and replacement of the P/Q mask with the MBU 12/P. This report details the complex history of the related events to date. It is intended to be a reference document for personnel involved in the use or support of this equipment and perhaps also in efforts to evaluate and bring into service other types of Aviation Life Support Equipment. //

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INTRODUCTION

In 1978 a requirement was identified for a new oxygen mask and helmet for Canadian Forces (CF) aircrew in the air combat manoeuvring (ACM) role (1). The then current helmet, the Gentex DH41-2, was considered to be uncomfortable and to have an unacceptably restricted visual field, and the oxygen mask, the A13A with Pate suspension, was difficult to position and was unstable during ACM.

The NDHQ Engineering Authority for this equipment, now the Directorate of Aerospace Engineering Support (DAS Eng 4), requested the assistance of the Medical Life Support Division (MLSD) of the Defence and Civil Institute of Environmental Medicine (DCIEM) (2). From the beginning this program was a team effort involving aircrew and engineering authorities in NDHQ, Command and operational units. Progress was reported and discussed in depth at quarterly Aviation Life Support Equipment meetings at DCIEM and final decisions were made by NDHQ.

DCIEM conducted initial studies to clarify shortcomings of the current equipment and to obtain aircrew ranking of design characteristics. Subsequently, potential replacement equipment and modification of the current equipment were studied and then a maintenance and flight trial of the most promising helmets and masks was conducted at CFB Cold Lake. Forty-eight aircrew flying primarily the CF5 and CF104 aircraft were involved. The results of these evaluations (3) suggested that the most suitable helmet and mask system for use in CF ACM aircraft was the then designated Model 190 helmet, which was made by Gentex and included the cutaway PRU 36P dual visor system, and the modified British W oxygen mask with a newly developed wire suspension system. It was acknowledged that there were still some deficiencies related to the visor weight, centre of gravity and profile; however, as capital funds for the new equipment were available in FY 82/83 and the equipment was urgently wanted by field units, it was decided to proceed promptly with acquisition and thoroughly address the deficiencies concurrently, rather than delay acquisition (which would jeopardize overall program funding) or hurry resolution of the problem (which might result in a "bad" fix).

Unfortunately, the W mask never reached commercial production (the units evaluated by MLSD were prototypes). The evaluations had indicated that the in-service British P/Q was the next best option, and in fact had the added advantage of having many components in common with the aircrew chemical defence respirator being adopted by the CF, the AR5. Consequently, NDHQ initiated procurement of the P/Q mask, with the wire suspension system of the W mask - which was also being adopted with the AR5, and the Model 190 (see Figure 1). Initial issue of the new equipment to aircrew of the CF5 and then arriving CF18 was to start early in 1983; however, the last minute change from the W to the P/Q mask and manufacturing difficulties with the P/Q delayed this by about one year (4). Further, when this equipment was introduced numerous problems were encountered which had not been evident during the evaluation stages. Nearly all of these were overcome but in the process the Model 190 helmet had to be substantially modified. For example, a drastically different single visor system was adopted while work proceeded on development of a better dual visor system. Ultimately, the P/Q mask was replaced by the Gentex MBU 12/P due to aircrew preference even though there

had been no clear preference between the W, P/Q and MBU 12/P masks during previous evaluations. (The W and P/Q had both been found to provide superior physiological performance and thus were the first choices.) This evolutionary process is still in progress but is finally nearing completion.

The purpose of this paper is twofold. First, it records the complex history of the helmet and mask system evolution since laboratory and operational trials were reported by Lazowski and Michas (3). Second, the paper is a status report on the latest version of the tasking of DCIEM on this subject (5) and, as such, it is hoped that it will be a useful reference document for personnel involved in the use or support of this equipment.

The history is organized and presented in the following sections:

- a. Problems with the Model 190 and P/Q;
- b. The search for a suitable visor system;
- c. The re-evaluation and adoption of the MBU 12/P;
- d. The evolution of the Thermal Plastic Liner (TPL);
- e. The situation today, Fall 1987;
- f. Future considerations; and,
- g. Lessons learned.

Selected key dates in this history are listed in Annex A.

PROBLEMS ENCOUNTERED WITH THE MODEL 190 AND P/Q

Many problems with the Model 190 helmet and P/Q mask became evident soon after issue had commenced. Some of these were anticipated but some were not. The most significant of these problems are listed below and what was done to rectify them is discussed in the following paragraphs:

- a. Microphone sensitivity;
- b. Earphone cord length and location;
- c. Wire suspension failures and adjustment difficulty;
- d. Mask oral-nasal facepiece cracking;
- e. Mask fitting difficulties;
- f. Breathing resistance during high acceleration;
- g. Helmet fitting difficulty and discomfort;
- h. Helmet forward rotation; and,

j. Helmet weight, centre of gravity and restriction of vision.

Microphone Sensitivity

The sensitivity of the microphone in the P/Q mask to background noise level was most unacceptable with the CF5D and was reported formally by 419 Squadron (6). They found that intercockpit communication was "marginal at best" and concluded that before they could use the P/Q mask the problem would have to be rectified "by modifications to the microphone assembly or purchase of a totally new mask". Microphone performance of the P/Q had been found to be very poor during the original evaluation (3) but these were 300 ohm impedance microphones used by the Royal Air Force (RAF). The impedance of those that were ordered in quantity for the CF was 7.5 ohms and the NDHQ authority for aircraft communications systems, the Directorate of Avionics, Simulators and Photography (DASP 2), believed that these would perform acceptably. The microphones were configured without the on-off switch used by the RAF. Unfortunately, the 7.5 ohm types were also found to be unsatisfactory and the noise problem had to be addressed anew by DASP 2. DCIEM was not involved in this investigation. The addition of a resistance to the microphone to reduce sensitivity was attempted but was only marginally successful and unfortunately, no other solution was found (7). Accordingly, the noise problem remained and was the only serious problem with the P/Q mask that has not been adequately rectified.

Earphone Cord Length and Attachment

The earphone cord was found to be slightly too long and attached to the wrong side of the back of the helmet. These problems were easily rectified by moving the attachment from the right to the left side. A Modification Instruction was issued in April 1985 (8). Helmets ordered after this date were delivered with this attachment on the left side.

Wire Suspension Failures and Adjustment Difficulty

The wire suspension adopted with the P/Q mask was a new system that had been developed for the W mask. As mentioned earlier, it was also compatible with the AR5. This suspension was favoured over the hook and chain suspension normally used with the P/Q and AR5 because it was extremely light and provided less potential for injury (3). Unfortunately, operational use quickly indicated that it was very prone to fraying and subsequent failure where the wires enter the threaded adjustment end of the assembly, as shown in Figure 2. One of these failed after only 22 days in service and several failed during flight. This problem had been anticipated to some extent by DCIEM but, as in the case of the deficiencies with the PRU 36P visor system, rectification proceeded concurrently with acquisition.

This problem was communicated to the manufacturer verbally and was quickly rectified by the use of higher strength wires, better quality control, improved crimping and, most importantly, extension of the clear sleeve covering the wire bundles all the way to the threaded end of the assembly and into this assembly, as shown in Figure 3. This prevented the wire strands from rubbing directly against the metal of the threaded end of the assembly until the clear sleeve had been worn through first. MLS D tested

the effectiveness of these improvements and estimated that service life had been improved by a factor of about 17 (9). The improved wires were adopted during the Fall of 1985 (10) and few failures have been experienced with them since then. All AR5 masks delivered to the CF have improved wires.

Difficulties of adjusting the suspension wire length during flight were not considered serious enough to correct.

Mask Oral-nasal Facepiece Cracking

The CF experienced an abnormally high incidence of tearing of the silicon oral-nasal facepiece of the P/Q mask assembly in the area of the bridge of the nose, as shown in Figure 4. The RAF Institute of Aviation Medicine (IAM) was contacted about this but was not aware of any such problem in the RAF. Several months later though they acknowledged that they had recently been experiencing similar problems and that the cause was thought to be a recent change to the moulds used in the manufacturing process. The moulds were corrected and masks manufactured subsequently have not exhibited this problem. This same cracking problem was recently reported for the AR5 by CF aircrew in 1 Canadian Air Group (1 CAG) (11) and is being solved similarly.

Mask Fitting Difficulties

The P/Q mask is very different than the A13A and this drastic change gave rise to several related problems, some real and some only perceived. Unlike masks such as the A13A, MBU 5/P and MBU 12/P which have large chincups and fit under the chin, the P/Q has a reflective edge seal and uses the sulcus of the chin to maintain stability. In RAF experience it has been found to be very stable at high acceleration ("Gz") levels during ACM. Most CF aircrew became accustomed to the different feel of the P/Q mask fairly quickly, but many did not. In fact, some thought the mask to be unstable under "G". In this regard, the design of this mask and the wire suspension system made comfort and stability very sensitive to changes in location of the suspension receivers on the helmet. In particular, if the receivers were located too high, the mask tended to lift off the chin and create excessive pressure on the bridge of the nose, sometimes causing minor bruising. Further, with the mask hose attachment on the bottom left hand side of the mask, looking down often caused the mask to lift off the chin slightly. Careful fitting of the receiver assemblies on the helmet as the CF gained experience with this equipment minimized these problems and no additional action was taken to improve this further.

Breathing Resistance During High Acceleration

Several incidents involving oxygen flow restriction occurred with the P/Q soon after its introduction into CF service. They were limited to the CF18 aircraft only and were originally described as a restriction of air flow to the oxygen mask occurring only during high levels of acceleration (+6 Gz) while looking back over the right shoulder. Study of this by MLSD revealed that the inspiratory valve of the P/Q mask, located on the lower left, was opening due to inertial forces and thereby preventing or restricting exhalation due to compensation of the exhalation valve from the oxygen mask inlet hose. The aircrew who had experienced this problem were

simply unable to correctly identify the direction of the restriction while enduring the stresses associated with a high acceleration environment (12).

The study of this problem also revealed that the rubber flapper of the inspiratory valve was relatively new, having been introduced into service in 1980 to reduce breathing resistance. None of the many other users of the P/Q mask appeared to have experienced a similar problem, but it was surmized that the CF18 capability of high levels of sustained acceleration and cockpit environment which allows the pilot great freedom of head movement (i.e. allowing orientation of the inhalation valve axis in the "+Gz" direction) was a new experience for this mask. The study further revealed that the "mushroom" flapper used in the inspiratory valve prior to 1980 was not susceptible to this problem. The Aerospace Engineering Test Establishment (AETE) confirmed these results recently with flight testing and recommended CF use of the "mushroom" flapper with the P/Q (13). NDHQ has acquired quantities of the "mushroom" flapper and is arranging for their installation in the P/Q and AR5.

Helmet Fitting Difficulty and Discomfort

Difficulties were also experienced with the fitting of the Model 190 helmet using the new TPL. The CF was the first Air Force in the world to adopt the TPL in an aircrew helmet and, as a result, experienced all the difficulties of evolving, with the manufacturer, the best fitting techniques, including such basics as oven temperature and curing times. For example, initially the TPLs were not being compressed enough during fitting, thus causing the helmets to sit too high on the head. This in turn made it difficult, and sometimes impossible, to lower the earcups enough to properly accommodate the ears. It should be noted that CF aircrew were used to a suspension type helmet and hence took some time to get used to the new contact type Model 190.

The problem of getting the helmets low enough on the wearer's head to properly accommodate the ears had been experienced earlier, during the evaluations at CFB Cold Lake, and Gentex had been asked verbally to lower the earcup recesses of the helmet shells 13 mm for all CF Model 190s. Somehow this was not done as intended as Gentex simply trimmed the edge of the shell 13 mm lower in the area below the ears. This did lower the helmet edgeroll and facilitated fitting of the earcups lower to some extent, but not nearly as much as would have been accomplished by lowering the earcup recesses. Consequently, difficulty in fitting the first aircrew with the Model 190 continued. This led to recognition of the requirement for an extra-large size helmet and, because the TPL was not being compressed enough at this stage, also led to an initial gross overestimation of the required quantity of this size. However, as fitting technique evolved and improved and CF Safety Systems technicians gained more experience, it became possible to more accurately estimate the required quantities of each size and to properly fit all CF aircrew.

"Hot spots" or pressure points on the TPL were also common. In most cases these were removed by remoulding (refitting) the TPL, cutting away portions of it or using an improved velcro tab system for attaching the TPL to the helmet. This is discussed in more detail in the section on the TPL.

Helmet Forward Rotation

The Model 190 helmet was also found to be prone to forward rotation. Investigation of this revealed that the nape strap portion of the integrated nape and chin strap system was riding upwards on the back of the head and hence not providing the required resistance to forward helmet rotation. The nape strap also tended to crease or fold over and was a source of discomfort. These problems were successfully alleviated by the addition of a leather nape strap guide, shown in Figure 5.

Helmet Weight, Centre of Gravity and Restriction of Vision

The Model 190 helmet was also found to be too heavy. At approximately 1.4 kg (for the large size), it was only marginally lighter than the 1.5 kg DH41-2. Center of gravity was also found to be a problem, caused almost entirely by the PRU 36P dual visor system and contributing to the problem of helmet forward rotation. Finally, it was discovered at a meeting with Gentex in November 1984 that restrictions to lateral and upward visibility were caused by both the leather edgeroll of the helmet and the visor housing and track system. These problems were tackled and solved together.

It was observed that if the PRU 36P was removed and the "bungee" visor from the then newly developed US Air Force (USAF) HGU 55/P helmet was installed, the Model 190 edgeroll was found to limit visual field. Conversely, when the PRU 36P was installed on the HGU 55/P, which has a slightly larger facial opening than the Model 190, the PRU 36P visor housing and tracks limited visual field. The HGU 55/P "bungee" visor system was a single visor system in that only one of the two available visors could be installed on the helmet at one time. CF requirements, nevertheless, continued to call for a dual visor system so that at least one visor could be down at all times. However, at that time all compatible dual visor systems would restrict the visual field of the Model 190. Further, CF aircrew interest in the new HGU 55/P helmet was growing as this helmet was being introduced into USAF service. Accordingly, it was decided to evaluate further the HGU 55/P visor system while still pursuing development of a suitable dual visor system. The Model 190 facial opening was cut back the same as the HGU 55/P and the improved Model 190 with the "bungee" visor system, shown in Figure 6, was designated the Model 190A. Thirty Model 190A helmets were purchased by DCIEM and evaluated at CFB Cold Lake from April to July 1985 (14). The Model 190A was very well received. Weight (1.2 kg for the large size), centre of gravity, stability, comfort, and upward and lateral visibility were all found to be acceptable and the Base Commander recommended that the Model 190A with the single visor ("bungee") system "be adopted as the ACM helmet for high performance aircraft in the CF and that it be made available to aircrew as soon as possible" (15). This recommendation was implemented by NDHQ (16) throughout 1986 but work continued on finding a suitable dual visor system. This is discussed in depth in the following section.

Adoption of the "bungee" visor system had the added advantage of being much less likely to scratch the very expensive aircraft canopies. Prior to this it had been found necessary to cover the PRU 36P fibreglas visor housing with a chamois or equivalent to minimize the risk of

scratching the canopies.

The reasons why the CF simply did not adopt the USAF's new HGU 55/P rather than create its own new Model 190A at this stage are as follows. Externally both look the same; however, there are significant differences. The HGU 55/P has separate nape and chin straps in lieu of the integrated system of the Model 190/190A and this integrated system is considered to provide superior stability and retention (3). Further, the poured foam liner fitting approach used with the HGU 55/P is considered to be inferior to the TPL approach of the Model 190/190A (3). The fact that the USAF is now pursuing the TPL supports the earlier decision of the CF to pursue this new approach. The TPL is discussed in more detail in a following section.

THE SEARCH FOR A SUITABLE VISOR SYSTEM

As previously mentioned, it was recognized from the beginning that the PRU 36P dual visor system had deficiencies (3). However, at that time there were no better alternative systems. As CF Flight Safety policy at that time required a dual visor system, MLSD initiated a Research and Development (R&D) contract to Rexdale Tooling Industries of Toronto in June 1983 (17) to study the feasibility of developing a better dual visor system and they reported in November 1983 that significant improvements were feasible (18).

As a result, another R&D contract was let, to Biokinetics and Associates Ltd. of Ottawa in August 1984 (19), to design and build two different prototype visor systems for CF evaluation. Five designs were actually prepared by Biokinetics (20) but only the two most promising were selected for detailed evaluation (21). All systems were designed specifically to improve actuation ease and reliability, centre of gravity, weight, profile and visual field. Further details on these systems are provided later.

While this development was taking place at Biokinetics, however, the CF was changing the Model 190 to the 190A, as described earlier. As a result, Biokinetics was advised to ensure that their designs were compatible with the cutback facial opening of the Model 190A.

Concurrently, the helmet manufacturer, Gentex, knowing that the CF was dissatisfied with its PRU 36P, developed a prototype dual "bungee" visor system, shown in Figure 7. (Up to this time only a single "bungee" visor system was in service.) Although this system had limitations, primarily related to ease of visor operation and lack of independent visor operation, it was thought that it showed a lot of promise too. It was extremely light weight and could be used as either a single or dual visor system. In the single visor configuration (essentially a Model 190A), the large size helmet and visor weighed 1.2 kg; in the dual visor configuration, the assembly weighed 1.3 kg. It was recognized that the dual visor system would likely be prone to scratching but it was also fairly inexpensive and easily installed.

The dual "bungee" system underwent successful windblast tests at DCIEM (22) and it was decided to take several prototypes to CFB Cold Lake with the thirty Model 190A helmets mentioned earlier. This visor system was

demonstrated during the briefing to the aircrew who would be participating in the evaluation of the Model 190A. Its prototype nature and known limitations were emphasized and the aircrew were asked simply if they thought it was worth pursuing further. Unfortunately, one of the senior aircrew present immediately disliked the system, loudly voiced this dislike and no other aircrew ventured to dispute his opinion. While it seemed that this system would go no further, the prototypes were left at CFB Cold Lake anyway. The Trial Report on the Model 190A (15) did include the statements "Performance of the dual visor assembly on the trial helmets was considered unacceptable" and "It was reported to be awkward to use, and the green visor could not be lowered without the clear visor being in place." The comment on awkwardness was expected and is valid. The other comment is not accurate. Although Gentex originally assumed that the green visor would only be deployed over the clear (i.e. the clear was expected to always be down during flight), the green visor can be lowered with the inner clear visor still up; this is awkward but with practice not difficult.

In the meantime Biokinetics proceeded to complete the design and production of test quantities of their two visor systems, which are shown in Figures 8 and 9. Briefly, both systems use a pivoting visor support to improve ease of operation. Both permit visor operation using only the left hand, which had been specified as a CF requirement. Both systems use a detachable leather visor cover similar to the one used with the "bungee" visors. One of the systems uses a friction system to lock the visor in place during windblast; the other uses a track locking system. Only the track locking system permits independent visor operation. The friction and track locking systems weighed, respectively, 0.02 kg less and 0.05 kg more than the visor system of the original Model 190 helmet. By comparison, the dual "bungee" system weighed 0.10 kg less.

During this same period Gentex pursued improvement of their dual "bungee" visor system by the addition of spacers which they hoped would increase ease of visor operation (see Figure 10). This system was ready in the Fall of 1986 at the same time as the Biokinetics systems and it was decided to evaluate all three together at 425 Tactical Fighter Squadron, CFB Bagotville while the new Model 190A was being introduced (23). This evaluation took place from November 1986 to March 1987. The results are detailed in the 425 Squadron Trial Report (24) and Biokinetics' Final Report (25). Briefly, the 425 Squadron Report recommended that "pilots of ACM aircraft should be offered a choice between single and dual visor operation". Further, only two of ten evaluation aircrew disliked the dual "bungee" system and five of eight who used both the dual "bungee" system and one of the Biokinetics systems preferred the dual "bungee" system. However, this evaluation was rather limited both in number of participants and duration and was complicated by the simultaneous issue of the new Model 190A helmet (and MBU 12/P oxygen mask, discussed in a separate section later).

The results were studied by MLSD and NDHQ Directorate of Air Requirements (DAR) and DAS Eng personnel and, based on the following advantages, it was decided to pursue only the Gentex dual "bungee" system further, at that time:

- a. the system is sure to be less expensive, because of its simplicity;

- b. the system is lighter;
- c. retrofit does not require any modifications to the helmet, i.e. the system can be refined and introduced as many times as necessary very easily, quickly and cheaply; and,
- d. the system can be used as either a dual or single visor system.

Unfortunately, the importance of this last feature had not been appreciated when the contract was let to Biokinetics and hence had not been stated as a requirement in their contract. Further, since then the Directorate of Flight Safety appears to have relaxed its earlier steadfast position on the dual visor requirement and may now allow a single visor to be worn on the helmet when only one type is required for the entire flight, i.e. at least one visor still has to be down at all times.

Refinements are being pursued now. They involve primarily improvements to ease of operation and removal of the slight restriction of field of view caused by the means of attachment of the "bungees" to the polycarbonate of the lenses, as shown in Figure 11. Interestingly, the USAF has not seen fit to rectify this same restriction with the visors of their HGU 55/P, even though this appears simple. Modified systems, perhaps such as that shown in Figure 12, should be available for field evaluation early in 1988; in the meantime, aircrew are using the Model 190A with single "bungee" visors. At the present time the USAF, Germany and Australia are studying the dual "bungee" visor systems being developed by Gentex and the CF.

RE-EVALUATION AND ADOPTION OF THE MBU 12/P

It was always expected that the P/Q oxygen mask would not please all aircrew. As has been mentioned already, Lazowski and Michas (3) concluded "It is difficult to discern the aircrew preference between the W, P/Q and MBU 12/P oxygen masks." Advantages and disadvantages to each existed as illustrated by the following excerpts from the report:

a. MBU 12/P mask

- (1) "Half of the aircrew involved in the flight trial reported that the MBU 12/P was comfortable, emphasizing the weight and feel of the mask. Interference with vision was reported to occur during start-up when the mask hung from one attachment point and obscured the enunciator panel. The suspension straps also interfered with vision in flight"; and,
- (2) "Extremely uncomfortable mask - larger inner seal interfered with mouth movement. Hot spot on bridge of nose, air leakage into eyes. Microphone unreadable and proved to be a flight safety hazard. Insufficient adjustments for mask. When mask disconnected it obstructed vision on one side of cockpit. Unable to fit three pilots with mask due to facial

structure. Use of mask discontinued due to flight safety."

b. P/Q mask

- (1) "Positive comments focused upon its stability under "G" and toggle system of rapid tightening";
- (2) "Some pressure points in the nose area for those people with large noses"; and,
- (3) "microphone very poor - garbled and incomprehensible".

The hook and chain suspension of the P/Q was disliked but was replaced by the wire suspension system of the W mask, subsequent to flight evaluation.

Other problems with the P/Q became evident after its introduction, as described earlier, but all of these were solved, except that of microphone sensitivity. Several aircrew at CFB Cold Lake, however, persisted in criticizing the P/Q. They went so far as to claim that they could not be properly fitted with either the P/Q or old A13A but that a proper fit could be obtained with the MBU 12/P (26, 27). As the A13A had been the only oxygen mask in CF service for years before this point, this author wonders how these individuals were able to fly previously! The criticism by these few individuals and the unsolved microphone problem with the P/Q eventually led NDHQ DAR to issue a Trial Directive in August 1985 (28) to operationally re-evaluate the MBU 12/P mask and "to compare its capability as an ACM mask to that of the P/Q mask." CFB Cold Lake was tasked (29) to carry out the trial and DCIEM purchased and forwarded a total of 34 MBU 12/P masks.

Two Trial Reports were received, one from the aircrew involved who had been transferred to 1 CAG during the course of the trial (30), and the other from the aircrew who remained in CFB Cold Lake (31). The basis of the 1 CAG report was the personal opinions of six aircrew. It was not an objective evaluation - almost all aspects of the P/Q mask were severely criticized while similar aspects of the MBU 12/P mask were accepted without critique. In contrast, the trial participants at CFB Cold Lake conducted a balanced and objective evaluation of both masks and produced a comprehensive report.

MLSD studied the CFB Cold Lake Trial report and forwarded comments to NDHQ in January 1986 (32). Briefly, DCIEM argued that there were really only two key problems with the P/Q, microphone noise and lack of user confidence. There was little if any progress by DASP on remedying the microphone sensitivity problem even though this did not seem to be an insurmountable problem. The lack of user confidence in the P/Q was seen to stem from the microphone problem and the wire suspension failures. As the wire suspension had just been improved, there remained only the microphone problem. The advantages of having a common mask and AR5 wire suspension system were re-emphasized but, as a contingency, a common bayonet suspension system was developed and described. The MBU 12/P mask uses the current USAF offset and angled bayonet suspension, shown in Figure 13, which was incompatible with the AR5, but an alternative bayonet system based on straight "T" bayonets used earlier by the USAF appeared compatible. This is

shown in Figures 14, 15 and 16. DCIEM prepared draft modifications covering installation of this common bayonet system on the AR5, P/Q and Model 190A, again, as a contingency (33). A very similar and compatible system, shown in Figure 17, was already proven and in use with some DH 41-2 helmet and A13A mask combinations (34). This approach thus offered a common suspension system for all CF helmets and masks, including the AR5. 1 CAG, tasked in October 1986 (35) to evaluate this common suspension on the MBU 12/P and AR5, reported in July 1987 that this system was effective and acceptable and recommended that it be adopted for operational use (11). However, it has since been decided to issue aircrew dedicated helmets for Chemical Defence and while a common suspension system is thus no longer necessary, it still has its advantages and a final decision is yet to be made by NDHQ (36).

Regarding the dedicated helmet for chemical defence, in order to use some of the quantities of the then surplus Model 190, MLSD prepared a draft Modification Instruction to replace the PRU 36P visor system with a tinted "bungee" visor (37). The facial opening of the helmet is not cut back because this modification is difficult and not necessary for visibility as this helmet configuration is only anticipated to be worn with the AR5, which already restricts visibility. Nevertheless, consideration is still being given to modifying the facial opening because the Model 190 pushes down on the facepiece of the AR5, which in turn causes pressure on the bridge of the nose for some aircrew (11). If the number of aircrew so affected is small, an alternative solution would be to issue these aircrew a second genuine Model 190A rather than a modified Model 190 for NBC operations.

Returning to the DCIEM letter (32), it was further argued that the conclusion of the CFB Cold Lake report (31) that "the MBU 12/P can satisfy a large majority of the users" was also true for the P/Q. A comment by pilot number 5 of the 1 CAG trial group (30) exemplifies the emotional attitude of many of the trial aircrew in this regard. He said "I was fitted with an MBU 12P mask by DCIEM/DAR because the P/Q would not fit my face adequately. If it cannot fit all the people, the PQ should not be in use. I want my MBU-12/P!" He and many others failed to appreciate that the MBU 12/P "cannot fit all the people" either and also that many aircrew still preferred the P/Q. In numerous private conversations with squadron aircrew during this project, opinions about the P/Q did not match those reported. These aircrew were unwilling to state publicly opinions contrary to those of the aircrew who preferred the MBU 12/P. This author believed and still believes that aircrew as a group still have no clear preference between the MBU 12/P and P/Q - assuming of course that the P/Q microphone problem could be fixed.

DCIEM concluded that "continuing with the P/Q mask as primary, perhaps with a bayonet suspension, and providing limited numbers of MBU 12/P masks for "special case" aircrew may be more practical than the reverse since P/Q masks are currently in the CF supply system and are similar to the AR5." A second DCIEM letter on this topic, prepared by the Director of the Biosciences Division (38), was submitted to NDHQ in January 1986. It described current research efforts to combat loss of consciousness during "G" through the use of positive pressure breathing (PPB). It argued that a PPB system requires an oxygen mask capable of sustaining PPB to a level of at least 70 mmHg and that the only mask currently in use that will do this is the P/Q; the MBU 12/P mask will barely sustain PPB to 30 mmHg. It concluded that "a major buy of MBU 12/P masks now may not be the most cost-

effective option when all evidence points to the requirement within a few years for a mask which will maintain high levels of PPB. At that time, the P/Q mask may not prove to be optimal for the new life support system, but it can then be replaced with a new state-of-the-art PPB mask."

Fighter Group (39) and Air Command (40) supported the CFB Cold Lake recommendation to adopt the MBU 12/P. Specifically, Air Command proposed that the MBU 12/P become the standard oxygen mask for aircrew employed on high performance aircraft (CF-18 and CF-5) and that exceptions to this be permitted only in cases where an individuals facial anatomy makes correct fitting of an MBU 12/P impossible. In March 1986 NDHQ DAR approved the Air Command proposals (16) and acquisition of the MBU 12/P was initiated. The fact that the P/Q mask costs about four times as much as the MBU 12/P was a major factor in this decision. The MBU 12/P mask and Model 190A helmet were introduced into service in CFB Cold Lake, 1 CAG, CFB Bagotville and CFB Chatham from October to December 1986. DCIEM instructed Base personnel on fitting of this new equipment and assisted in the fitting of the first aircrew at each at these units.

As might be expected, problems arose during the fitting and subsequent use of the MBU 12/P. The most serious of these was leakage from the mask at the bridge of the nose and flowing into the eyes. This had been reported by Lazowski and Michas (3). The problem was "solved" in the USAF and USN by use of a "custom fit kit", a 13 mm by 76 mm piece of maleable metal covered with 2 mm thick foam which could be inserted into the bridge of the nose area of the mask. It is used to contour this area so as to prevent leakage (see figure 18). CF users found this to be only marginally successful at eliminating leaks and retention of the inserts in the mask was not reliable. A suitable adhesive was identified and used to improve reliability (41) but this approach was messy and several aircrew still could not get adequate fits. Fortunately, these individuals had achieved good fits with the P/Q and so were authorized to continue using it (42). The P/Q mask has an 8 mm by 54 mm piece of maleable metal, stiffer than that used in the MBU 12/P "custom fit kit", permanently moulded into the area of the bridge of the nose. This has been used very successfully. Upon DCIEM suggestion, Gentex is investigating incorporating a similar feature into their MBU 12/P.

Contrary to expectations, inserting the current bayonets (offset and angled) further into the receivers on the helmet to tighten the MBU 12/P mask often degraded rather than improved facial seal, and increased leakage. In many cases this was due to the geometry of the bayonets, i.e., inserting the bayonets further pushed the mask upwards on the face as well as back towards the face (refer to figure 13), and this often caused unacceptable discomfort at the bridge of the nose and below the eyes. The alternative bayonet suspension mentioned previously (straight "T") is inserted horizontally (vice upwards at approximately 45 degrees) and was often found to be better in regards to this problem.

Paradoxically, three months after introduction of the MBU 12/P into 1 CAG, the Base Aviation Life Support Equipment Officer attended one of the regular Aviation Life Support Equipment Project Review Meetings held at DCIEM (43) and indicated that many 1 CAG aircrew wished they still had the P/Q, i.e. they were quite unhappy with the MBU 12/P. Unfortunately, this

was not recorded in the minutes. One of the original MBU 12/P advocates at 1 CAG responded to this criticism by claiming that the CF had not ordered one of the MBU 12/P mask sizes and by insisting that the CF fitting of the MBU 12/P mask was improper (44). Neither of these assertions was true.

Further, aircrew did not appreciate that a pilot descending in his parachute after an ejection in the CF 18 is in jeopardy of suffocating if he is unable to doff his mask or disconnect the mask inlet hose from the oxygen regulator. This stems from the fact that the oxygen regulator in the CF 18 has a built-in warning feature whereby flow to the mask is stopped if the inlet pressure to the regulator drops below 40 psi. This is to warn of inadvertent disconnection of the oxygen supply to the regulator. However, this means that when the emergency oxygen bottle pressure drops to below 40 psi after ejection, flow to the mask stops. An uninjured pilot could then doff his mask or disconnect his mask hose from the regulator. (The emergency oxygen supply will last long enough for him to get down to a low enough altitude to allow breathing ambient air without becoming hypoxic.) An injured aviator though runs the risk of suffocating. Consequently, DCIEM studied and recommended incorporating an anti-suffocation valve in the MBU 12/P similar to the one used in the P/Q (45).

Other problems encountered with the MBU 12/P were minor in nature and were rectified fairly easily. For example, this microphone also picks up unacceptable levels of background noise, especially in the CF-5D. Fortunately though, the application of a thin coat of silicone on the side of the microphone facing the combination inhalation/exhalation valve appears to reduce this noise to an acceptable level (46). The bayonets tended to pinch the cheeks of one pilot; this was fixed simply by slightly decreasing the offset of his bayonets.

The one serious problem that still remains is that of mask leakage at the bridge of the nose. Further, despite the optimism for the MBU 12/P of the trial aircrew, the simple fact is that it does not "fit all the people" any more than the P/Q did!

THE EVOLUTION OF THE THERMAL PLASTIC LINER (TPL)

The thermal plastic liner was developed by Gentex in the late 1970s and, as mentioned earlier, the CF was the first to adopt it in an aircrew helmet, i.e. in the Model 190 and 190A. It has undergone several improvements since it was first used in the Model 190. At first the TPL was delivered as a single unit with an inner cloth lining glued to the plastic layers, as shown in Figure 19. Partial or full coverage, washable, cotton skull caps, shown in Figure 20, were used to reduce soiling of the lining by sweat or hair oil. These often facilitated donning of the helmet. These skull caps have since been used to advantage with other helmets too.

Initially the velcro tabs used to secure the TPL in the helmet were installed by the manufacturer in predetermined locations (front, back and each side). The tabs on the TPL were of the hook type and those installed in the helmet were the pile type. The front tab pair was found to cause a hot spot for many wearers. Gentex solved this by changing the helmet velcro tabs to the hook type and leaving them separate from the helmet to allow

users to install them where they preferred. The recommended locations are midway between the original locations but any locations which hold the TPL in place will do. Concurrently, the TPL liner was modified to include a larger outer band of velcro pile. Gentex next decided to make the cloth liner detachable and hence washable. This liner and an untrimmed TPL are shown in Figure 21. This eliminated the need for skull caps but many aircrew still prefer to use them. It also made it possible to trim the TPL as necessary to achieve a better fit and improve comfort. This is not limited to trimming of the edges; since the TPL is simply a fitting device and does not add significantly to the protective qualities of the helmet, whole or parts of layers may be removed, for example, to lower the helmet on the head slightly to achieve a better fit of the earcups, or to remove a hotspot. These changes are easily made and have been used very successfully. Consider the ease of this approach compared to the complexity of adjusting the strap suspension of the DH 41-2.

The TPL fitting technique also proved very useful in solving another problem. When the Model 190A was being introduced into service in 1 CAG in the fall of 1986, the problem of obtaining clearance of the visors over eyeglasses arose. The helmet is normally fitted sufficiently far back to produce an unobstructed field of view. Unfortunately, this almost always made the visors contact the upper corners of eyeglasses. This was solved simply by altering the fitting procedure to move the helmet sufficiently forward to obtain adequate clearance (47). This sometimes reduced field of view slightly but was judged an acceptable compromise.

In order to avoid the requirement for the custom fitting process of heating and moulding the TPL for most aircrew, Gentex now pretrims (again) and premoulds the TPL. They claim that 95% of the aircrew can be fitted by simply selecting the appropriate size. In other cases, the TPL can be reheated and remoulded. Further trimming is also possible since the cloth covers are still removeable. These features make fine tuning the fit of the Model 190/190A easy compared to the DH 41-2 or most other strap suspension helmets.

The TPL has proven to be a very versatile and relatively inexpensive method of fitting helmets, and other nations are following Canada's lead. The TPL is being adopted in the HGU 55/P and is included in the developmental Tactical Life Support System (TLSS) of the USAF. Australia, Switzerland, Spain and the Netherlands are considering use of the TPL at this time. Gentex is also now offering an improved SPH series helmet, called the SPH 5, which uses the TPL and DCIEM is studying this as a potential long term replacement for the DH411.

THE SITUATION TODAY, FALL 1987

Today aircrew flying the CF-18 and CF-5 are wearing the Model 190A helmet and MBU 12/P mask with the current USAF offset and angled bayonet system. Those aircrew who could not be properly fitted with the MBU 12/P are using the P/Q mask with the improved wire suspension. Activities and progress of NDHQ DASP regarding P/Q (and AR5) microphone sensitivity are unknown. Gentex is studying the matter of MBU 12/P mask leakage around the bridge of the nose. NDHQ is considering the matter of a common suspension

for all high performance CF helmets and masks, including the AR5.

DCIEM is in the process of acquiring a limited quantity of an extra-extra-large size Model 190A for those very few aircrew whose heads are too large for the extra-large size (48). Gentex and DCIEM are also studying alternative earcups which are slightly lighter and intended to offer equal or better noise attenuation and (impact) energy absorption. An improved "dual bungee" visor system is being refined at DCIEM for subsequent operational evaluation. 410 Squadron CFB Cold Lake reported in June 1987 that visor fogging with the Model 190A and MBU 12/P was a serious problem (49) and requested permission to prototype foam spacers on the top edgeroll to permit some airflow and hopefully prevent or at least reduce this fogging. This problem had been reported in the original evaluation of the Model 190A (15) but has been mentioned only casually since then. As a result little has been done to correct this. DCIEM refined the 410 Squadron suggestion but observed that the windblast capabilities of the reconfigured helmet might be jeopardized. Nevertheless DCIEM recommended to Air Command that this solution be prototyped and evaluated by 410 Squadron (50), which is now in process (51).

FUTURE CONSIDERATIONS

There are no plans to replace or improve significantly the Model 190A helmet or MBU 12/P mask at this time. However, should the CF adopt a system similar to the USAF TLSS, a TLSS helmet and mask would be required. Similarly, should Night Vision Goggles be required in the CF-18 or CF-5, a different helmet will be required because the goggles' mounting systems are incompatible with the "bungee" visor system. The weight of the Model 190A helmet could be reduced by approximately 0.2 kg by the use of Kevlar in lieu of fibreglas in the shell. This is being studied by Gentex but is not being actively pursued by the CF. CF interest would increase if the USAF should adopt a Kevlar HGU 55/P or if there was a stated requirement for this reduced helmet weight.

LESSONS LEARNED

The greatest lesson to be learned from this programme is one that is timeless and that perhaps all should have appreciated more from the onset, namely, you cannot please all the people all the time. Several aircrew genuinely could not be properly fitted with the P/Q mask but could with the MBU 12/P. But is it surprising that about the same number of aircrew cannot be fitted with the MBU 12/P and can with the P/Q? Was it really beneficial and appropriate to reverse the decision to adopt the P/Q when hundreds had already been purchased and delivered? Only if the microphone problem was genuinely unsolvable should the answer have been "yes". It remains to be seen just how successful the MBU 12/P will be in CF service.

Although the path to the Model 190A has not been as direct as everyone would have hoped, the "final" product appears to be very good and indeed has stimulated the interest of other Air Forces. Herein lies another important lesson illustrated by the program - it takes a long time to introduce a new piece of equipment into service, in this case nine years

elapsing since the original Unsatisfactory Condition Report. Much of this time was used to overcome the human element of differing opinions as well as the many changes in the personnel involved in NDHQ, DCIEM, Air Command and operational units. Further, frequently after a solution has been declared, another option is identified and touted as "better". The process is dynamic and never ending but clearly cost also constrains repeated changes to equipment in the field. DCIEM, DAS Eng and DAR are required and continue to keep abreast of new developments; aircrew should understand the evolution process and that there will be compromises, and must at some point accept that their equipment is "the best available for now".

ACKNOWLEDGEMENT

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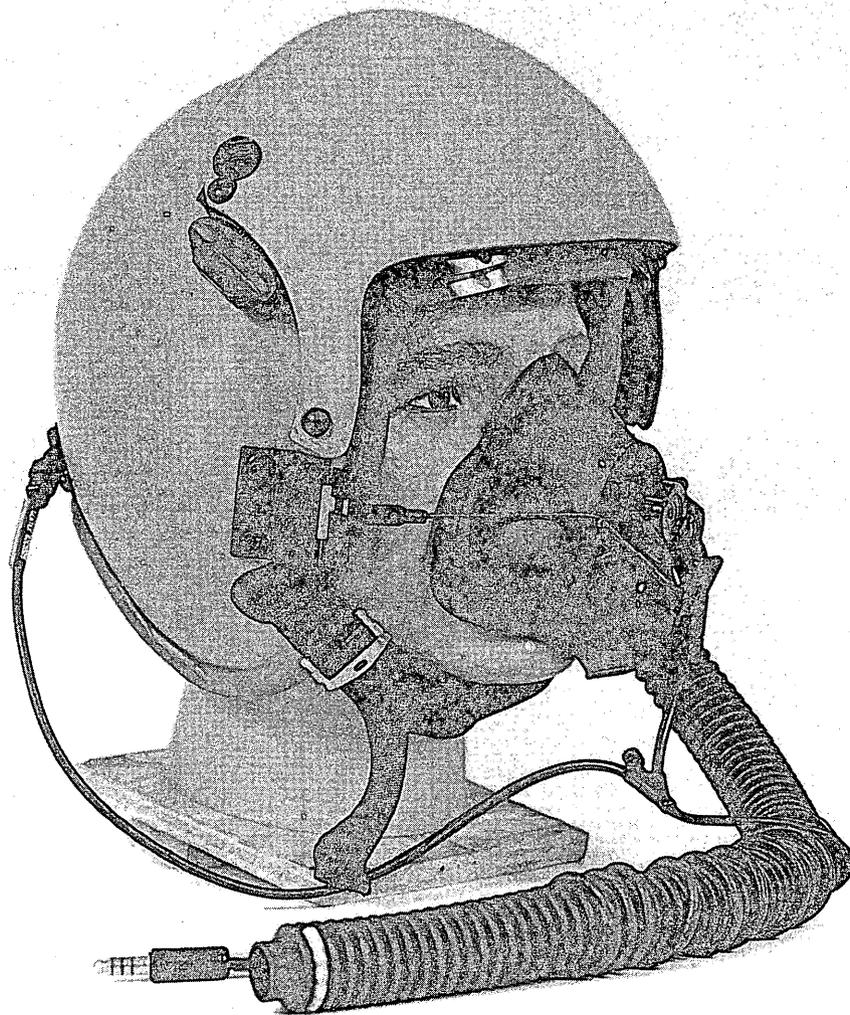


Figure 1. Model 190 Aircrew Helmet and P/Q Oxygen Mask
with Wire Suspension System

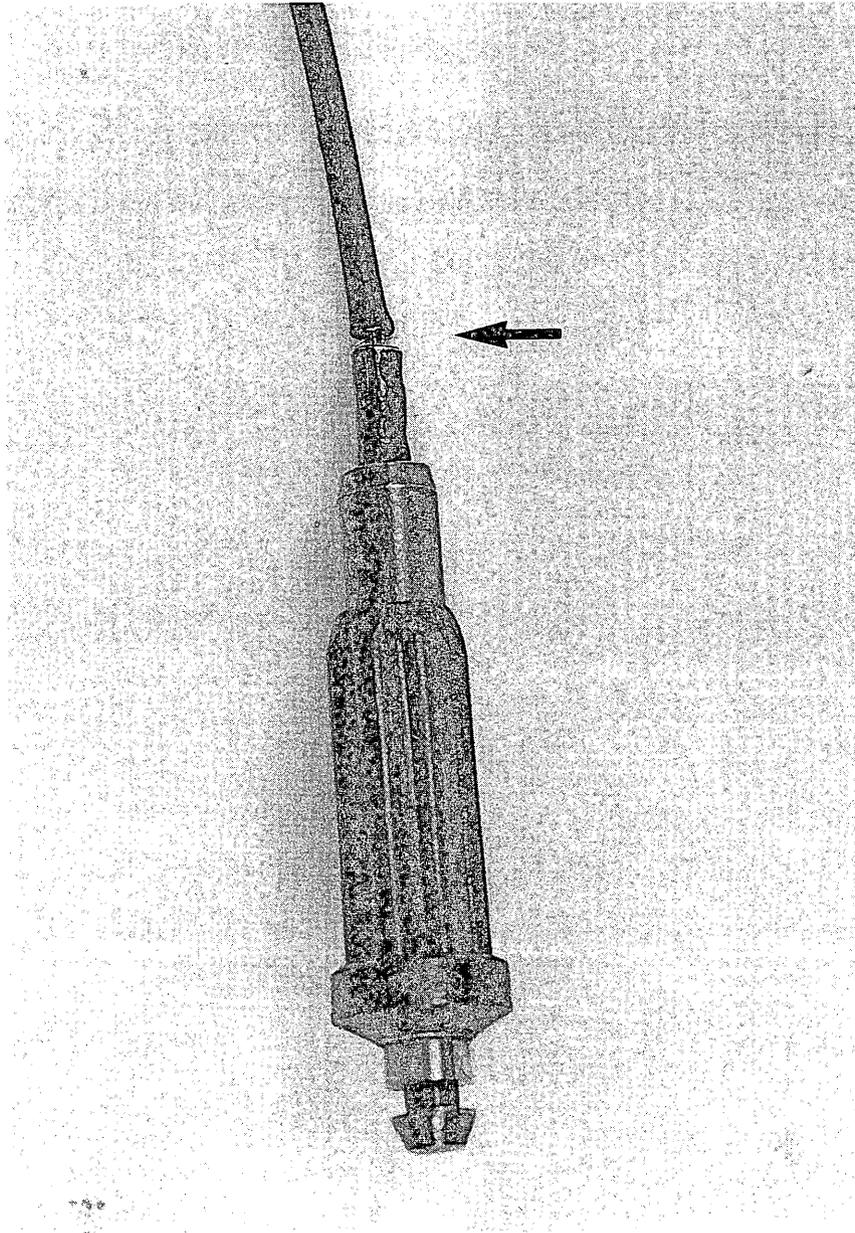


Figure 2. Frayed Mask Suspension Wire

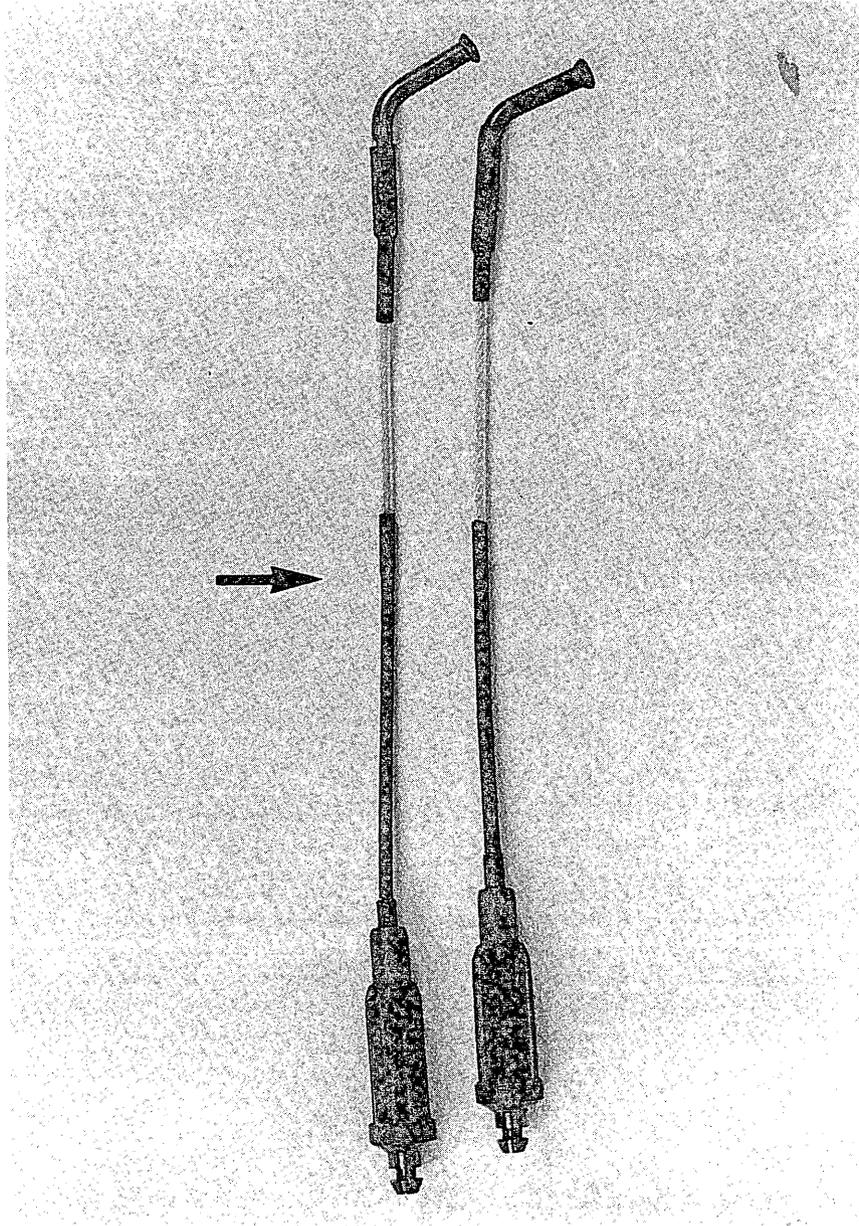


Figure 3. Original and Improved Mask Suspension Wires
(the arrow indicates where the sleeve ends on the original wires)

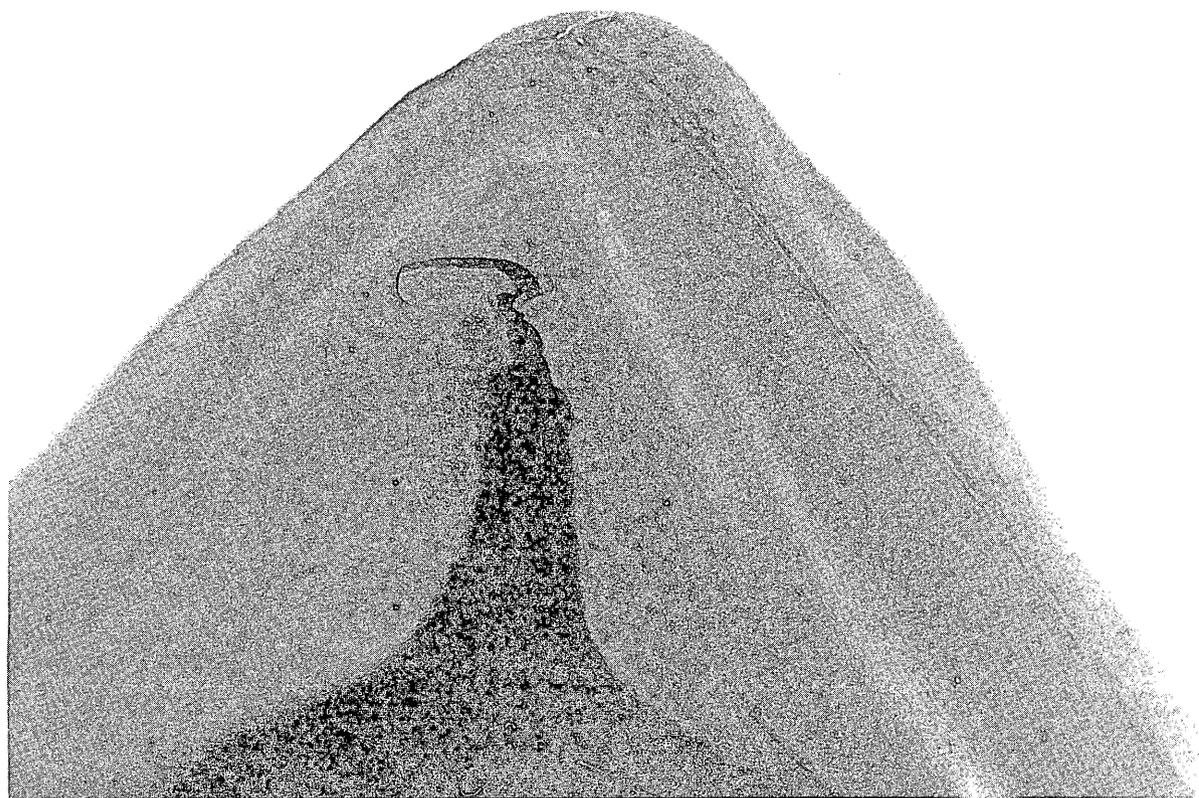


Figure 4. Torn P/Q Mask Oral-Nasal Facepiece

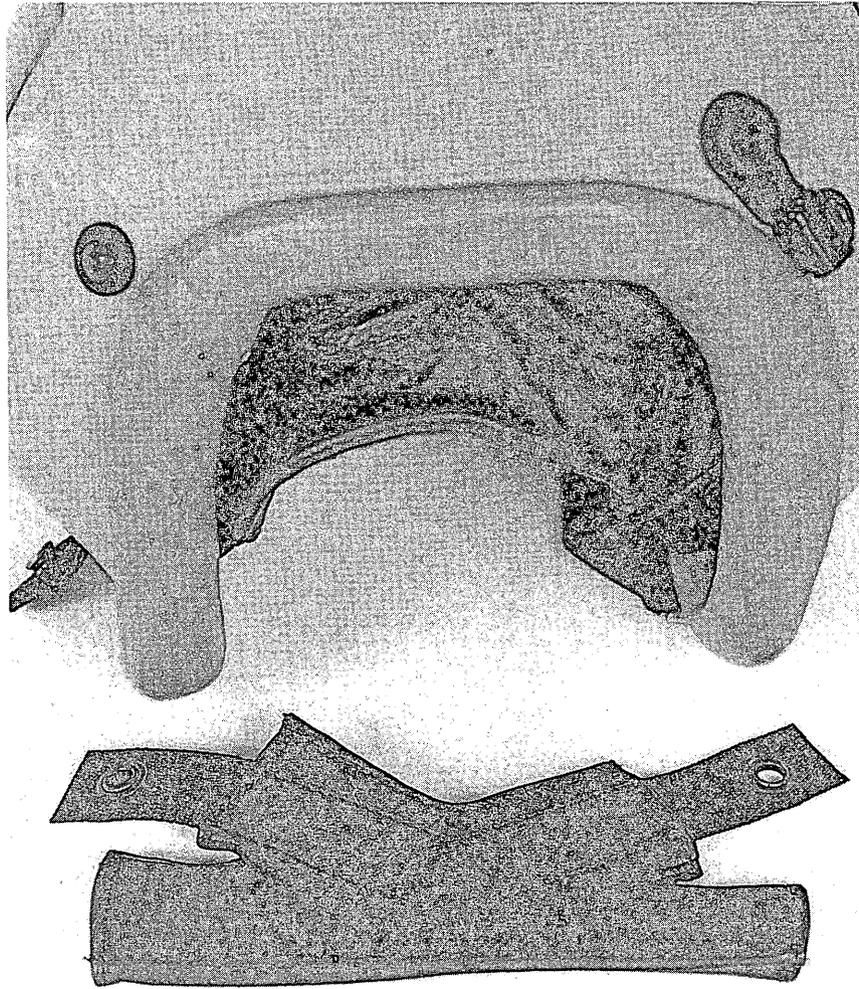


Figure 5. Nape Strap Guide for Model 190/190A Helmet



Figure 6. Model 190A Aircrew Helmet



Figure 7. First Dual "Bungee" Visor System



Figure 8. Biokinetics Track Locking Dual Visor System

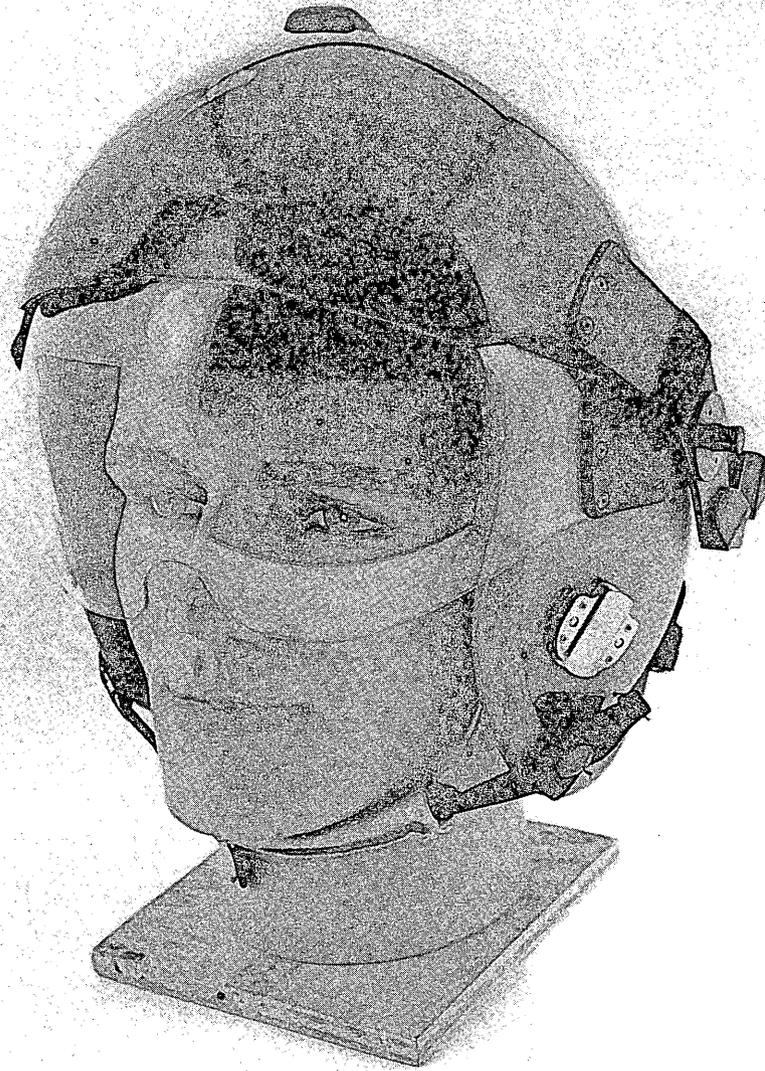


Figure 9. Biokinetics Friction Locking Dual Visor System



Figure 10. Second Dual "Bungee" Visor System (with spacers)

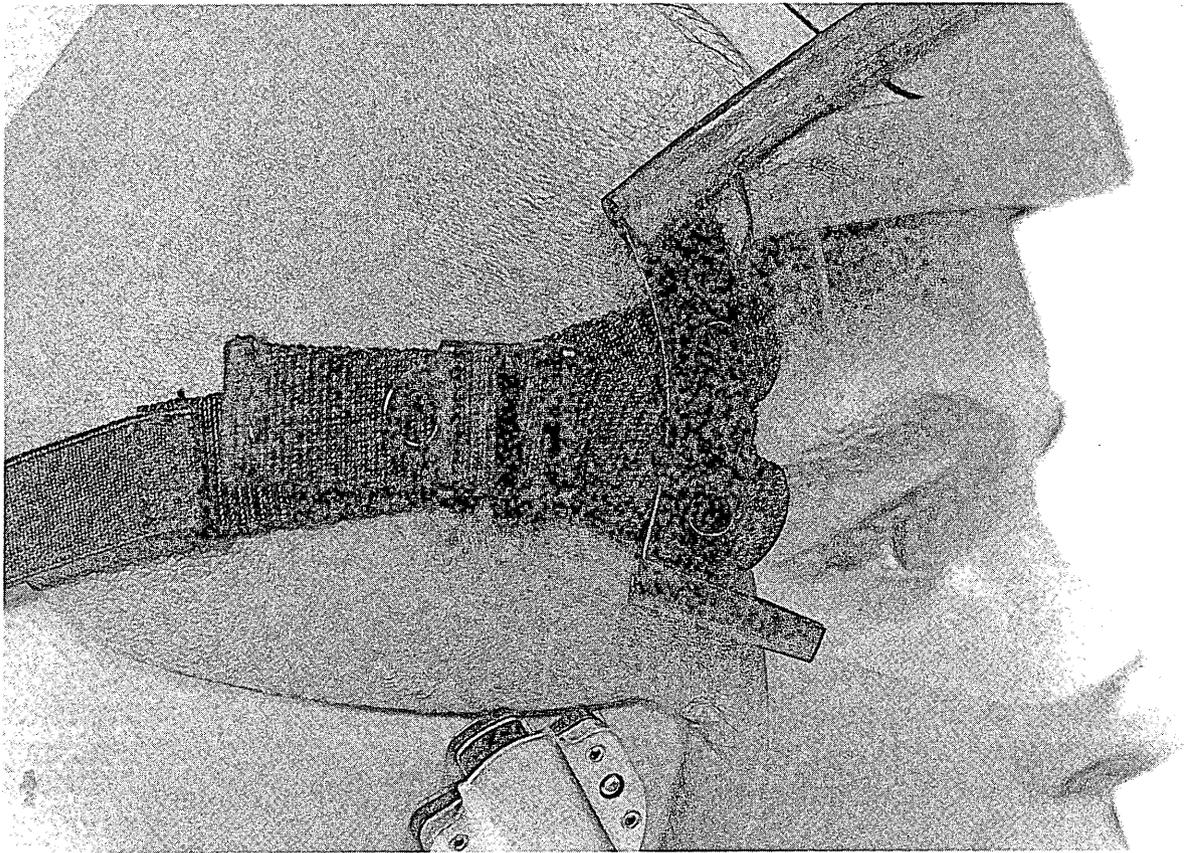


Figure 11. "Bungee" Visor Lens Attachment Showing
Restriction of Field of View on the Model 190A



Figure 12. Latest Dual "Bungee" Visor System



Figure 13. Angled and Offset Bayonet System on MBU 12/P

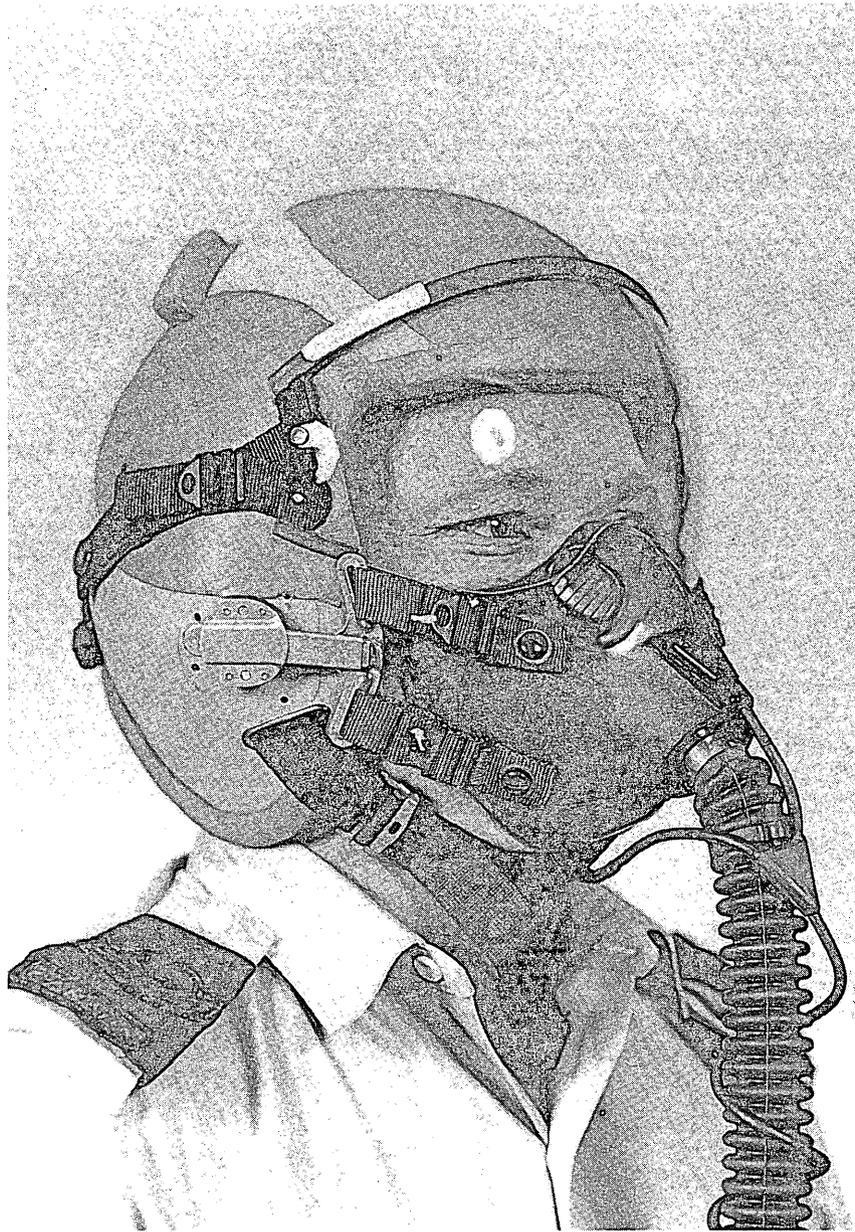


Figure 14. Straight "T" Bayonet System on MBU 12/P



Figure 15. Straight Bayonet System on AR5



Figure 16. Straight Bayonet System on P/Q

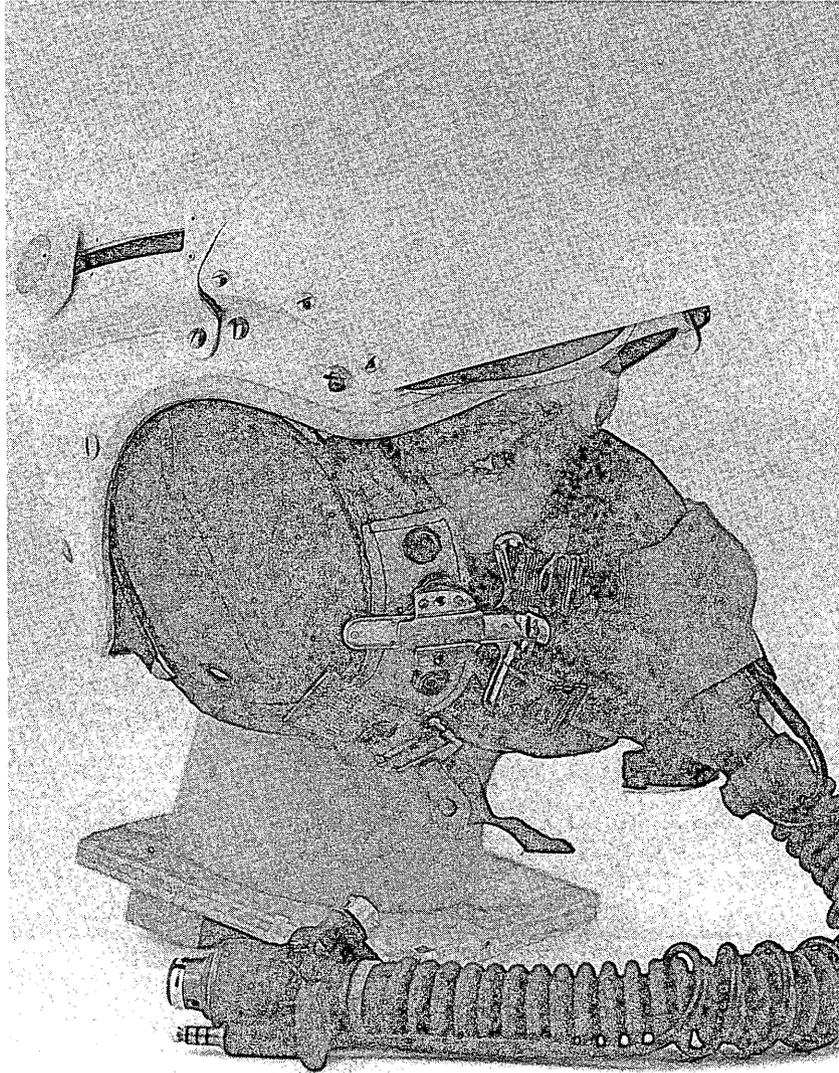


Figure 17. DH41-2 and A13A with Bayonet Suspension System

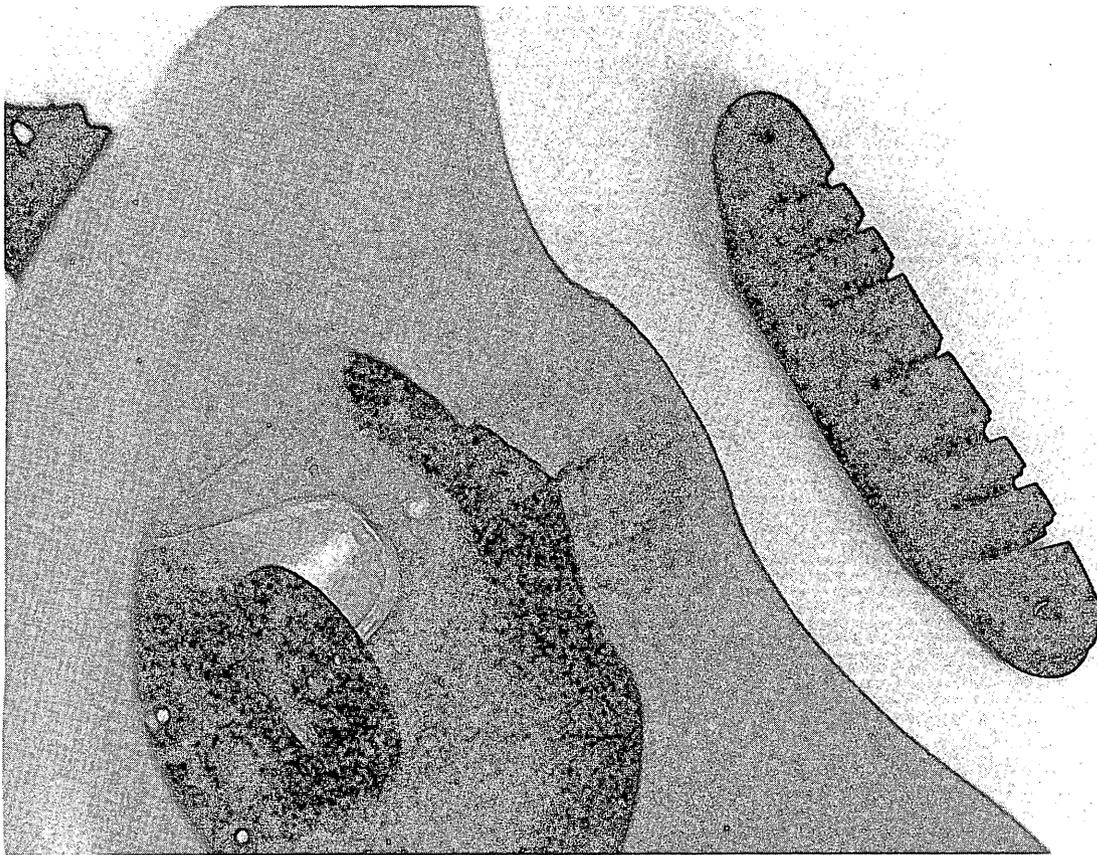


Figure 18. MBU 12/P "Custom Fit Kit"

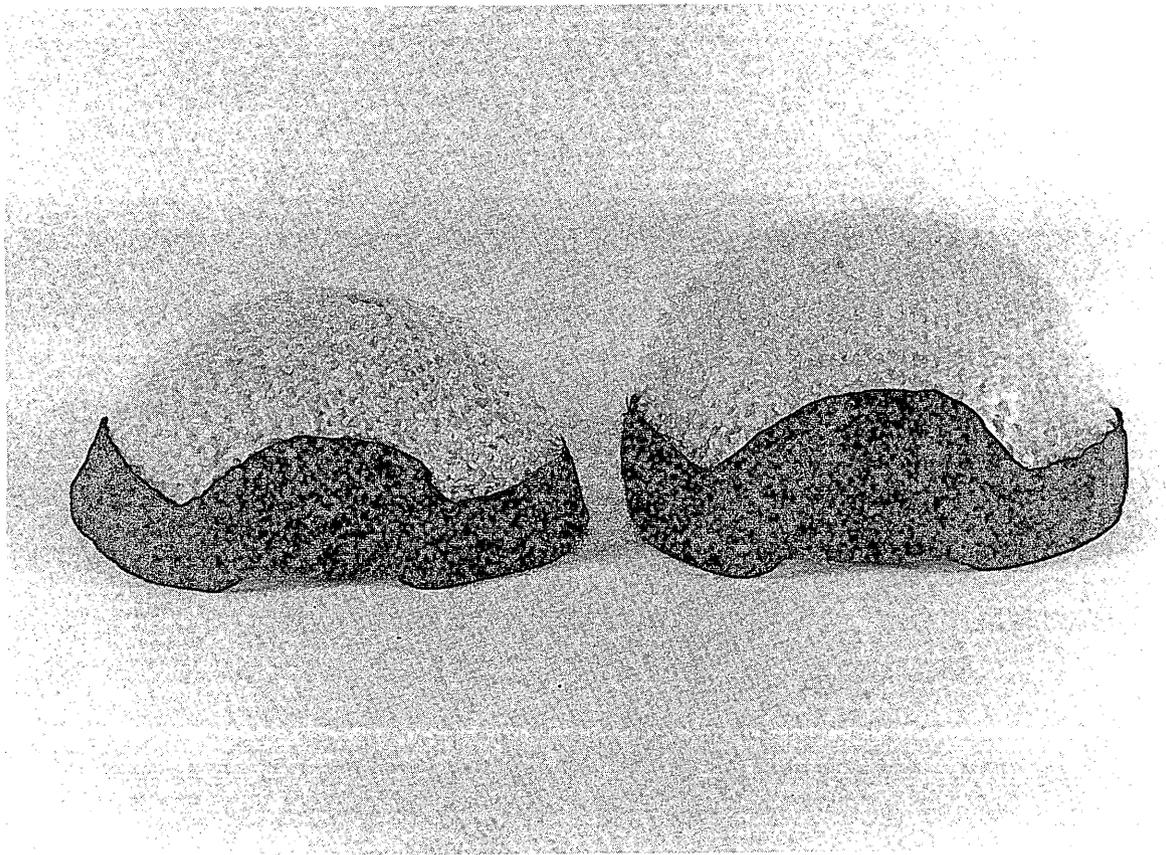


Figure 19. Original TPL for model 190 (fitted and unfitted)

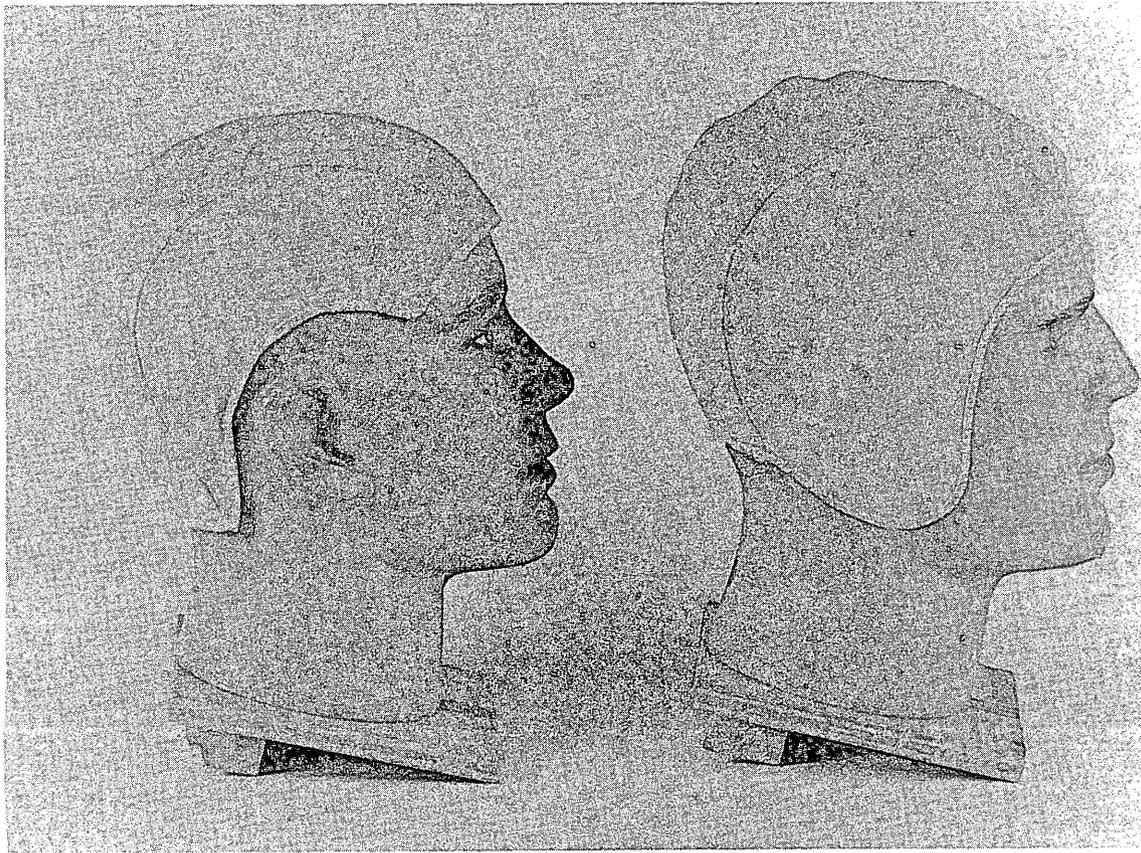


Figure 20. Partial and Full Coverage Skull Caps

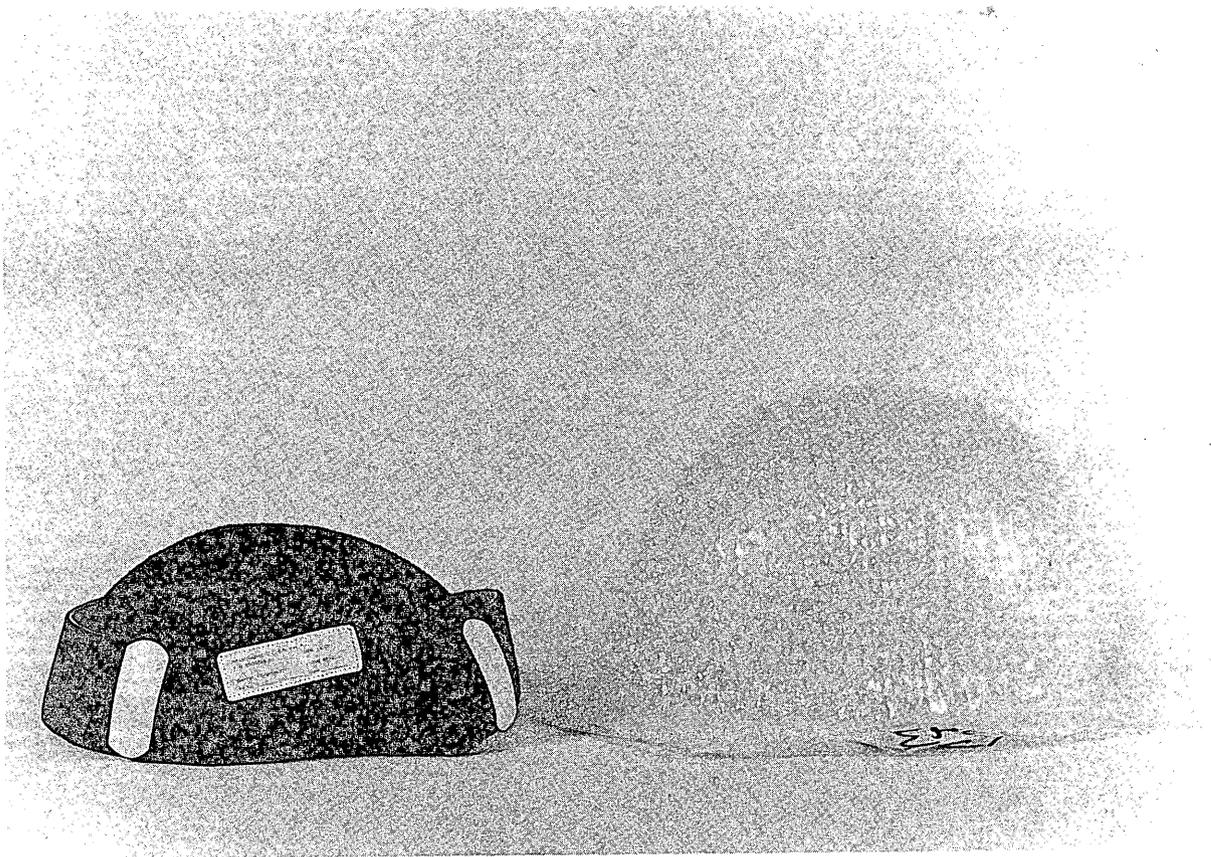
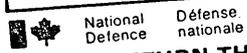


Figure 21. Removable Cloth Liner and Untrimmed TPL

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