

RESULTS ON A
KINETIC ANALYSIS
OF HOCKEY SHOTS

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INTRODUCTION

The purpose of this investigation is to measure the variation in time of the forces applied on a hockey stick by players while shooting at a target. The different shots performed are the sweep, the wrist and the slap shots, at rest and in motion. The velocities of the puck for slap shots are also measured and the influence of the shape of the time dependent forces on these velocities is studied.

During the course of this investigation, nine skillful adult amateur hockey players were used as subjects. Some of their characteristics are listed in TABLE 1. The subjects were not familiarized with the instrumented hockey sticks before the experiment. This fact could have had some influence on their performance since the umbilical cord is somewhat cumbersome at first. The experience was carried out in an indoor arena on october 17, 1974.

A list of reference on the subject of ice hockey shots have been presented in a previous publication and is given in appendix for the benefit of the reader.

METHODOLOGY

The forces produced by both hands and the reaction of the ice and of the puck on the stick were obtained using strain gages appropriately located along the handle and the blade of the stick (FIGURE 1). The technique has been previously tested in laboratory (see Ref. 22). Seven Wheatstone bridges were formed in such a way as to compensate for temperature variations during the tests (FIGURE 2). The output signals of these seven bridges and the three equilibrium force equations are, in principle, sufficient to determine the eight forces and the distances x_1 , x_2 as shown in FIGURE 3. G_1 and G_2 represent the reaction of the ice and of the puck on the blade, G_3 , G_4 and G_5 are the three components of the action of the upper hand on the handle and G_3' , G_4' and G_5' represent those of the lower hand. The parameters a and b , giving the location of the hands, were measured for each subject and for each type of shots. The output signals were amplified and continuously recorded on photosensitive paper travelling at a speed of 1 m/sec (FIGURE 4). The puck velocity was measured using a digital time counter, triggered and stopped by microphones sensitive to the noise of the impact of the blade on the puck, and the puck on the target. It was possible to calculate the velocities knowing the distance between the initial position of the puck and the target.

The instrumented hockey sticks have been statically calibrated to obtain the response of the Wheatstone bridges under flexion or traction of both blade and handle. The force analysis was performed, using the recorded outputs and the calibration constants, for time intervals varying from 0.01 sec. to 0.1 sec. depending on the rate of variation of the recorded signals.

RESULTS

The puck velocity was measured for slap shots at rest and in motion. Each subject made five of each type of shots. The mean value and the standard deviation of the velocities for the nine subjects as a group are given in TABLE 2. The mean value of the velocities for each of the nine subjects is given in TABLE 3.

Some of the time-dependent force diagrams obtained during this experiment are presented in FIGURE 5 through FIGURE 25. Forces G_3 and G_3' (FIGURE 3) could not be obtained accurately because of the relatively low sensitivity of the two Wheatstone bridges made of gages 5, 6, 7, 8 and 11, 12, 13, 14. However, the maximum value of these two forces is of the order of 20 Kg. For all time, G_3 and G_3' are approximately of equal intensity and act one against the other. Since these components of the hand reactions along the axis of the stick do not contribute to the puck velocity, it was not necessary, in our study, to determine their value with good accuracy. It was also difficult to obtain experimentally any meaningful value for the distance x_2 . This is due primarily to the relatively short spacing of gages 15 and 16. The value of the ice reaction G_1 was computed assuming the distance x_1 to be 2,5 cm. Of all measured forces, G_5 and G_5' are the most significant since they contribute directly to accelerate the puck. For all force diagrams, the time axis has been set such that the peak value of G_5' occurs at 0 sec. In some diagrams, as in FIGURES 7 and 23, the curves are truncated at the beginning or at the end of the shot; this is due to the late starting or early stopping of the recording system during the test.

INTERPRETATION OF RESULTS

The analysis of the results has revealed that some difference exists in the shape of the force-time diagrams between different type of shots performed by the same player (see FIGURES 5 - 10 for subject 1 and FIGURES 15 - 19 for subject 4). This difference should be visualized by studying the variation of G_4' and G_5' representing the action of the lower hand on the stick. For subject 1 (FIGURES 5 - 10), the maximum value of the most significant force G_5' is nearly a constant equal to 10 Kg except for the slap shot at rest (FIGURE 9) where, oddly enough, this maximum value is somewhat lower. This last result seems to indicate the importance of the impact of the blade on the puck for slap shots since, usually, the velocity of the puck for that type of shot is somehow higher than for the other types. This remark also applies for subject 4 (FIGURES 15 - 19). Even though these differences exist between different type of shots performed by the same player, a general pattern can be identified through the various diagrams, making possible the recognition of the "signature" of a player.

However, much dissimilarity exists in the force diagrams of different players performing the same sweep and slap shots. These differences can be visualized by comparing FIGURES 5, 13 and 15 for the sweep shot at rest, FIGURES 6, 14 and 16 for the sweep shot in motion, and FIGURES 10 and 20 or 21 for the slap shot in motion. Surprisingly, the diagrams are quite repeatable from one player to another for the wrist shots, as can be seen by comparing FIGURES 7, 11 and 22 (at rest) and FIGURES 8, 12 and 24 (in motion). This similarity could be explained by the fact that the wrist shot is less elaborated to perform than the other shots and thus allows a more uniform pattern for all players.

In the case of repeated shots in the same standard conditions by one player, the shape and intensity of the force-time diagrams do not show the similarity one could have expected. This dissimilarity is noticeable by comparing the curves G_4' and G_5' for the pairs of figures 16 - 17, 20 - 21, 22 - 23, and finally 24 - 25. Such non-uniformity may affect the velocity and the precision of the shots. Again, it is for the wrist shots that the pattern is mostly preserved.

The puck velocity for slap shots is not directly related to the maximum force intensity a player can produce on the stick. Figure 10 shows the maximum value of G_5 and G_5' to be 6 Kg and 10 Kg respectively while, for slap shots in motion the mean puck velocity is 26 m/sec for subject 1 (TABLE 3) where as these maxima are only 5 Kg and 2 Kg in FIGURE 21 yielding a puck velocity for subject 5 of 30,8 m/sec (TABLE 3). Therefore, the puck velocity seems to be highly sensitive to the shape of the diagrams and not so much to the maximum forces produced. This last observation indicates the importance of the kinematic of the motion performed while shooting.

CONCLUSION

Even though the present investigation do not produce numerous practical results, it has proved the usefulness and the effectiveness of the instrumented hockey sticks for force measurements. The recent development of a system using photoelectric cells to measure accurately the puck velocity for any kind of shot will permit a complete correlation between the dynamometric results and the puck velocities. The coupling of high speed photography with these methods of measurements will also permit to analyse the influence of the driving motion and of the applied forces on the efficiency of the shots. The use of instrumented sticks of various flexibilities will allow the evaluation of the influence of the characteristics of the stick itself on the maximum forces applied by the hands and on the puck velocity. These experiments will be carried out in the near future using highly skilled subjects of different levels. Ultimately, these studies will permit a better understanding of the kinematic and the kinetic of the different hockey shots in order to develop modern methods of training for young hockey players and to design hockey sticks that will be better adapted to the skill and the level of the players and to the type of shots most frequently used.

ACKNOWLEDGMENTS

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TABLE 2

PUCK VELOCITY FOR NINE SUBJECTS
(Mean value and standard deviation)

TYPE OF SHOT	VELOCITY (m/sec)	
	Mean value	Standard deviation
Slap shot at rest	26,9	1,5
Slap shot in motion	29,0	1,4

TABLE 3PUCK VELOCITY FOR SLAP SHOTS

(Mean value for five shots)

Subject	VELOCITY (m/sec)	
	Slap shot at rest	Slap shot in motion
1	24,6	26,0
2	28,3	29,8
3	25,2	28,7
4	28,3	29,4
5	28,5	30,8
6	27,5	28,0
7	27,6	29,7
8	26,9	29,6
9	25,8	29,4

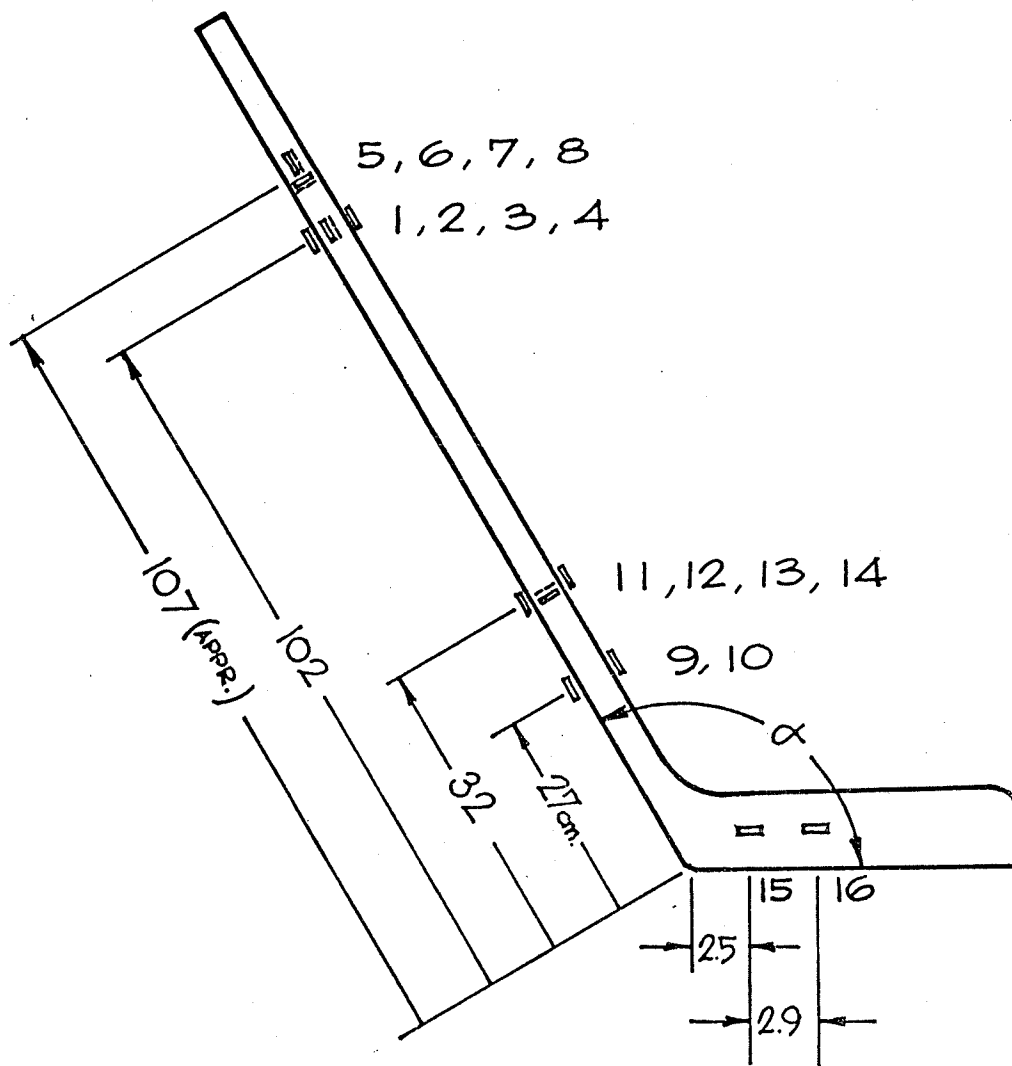
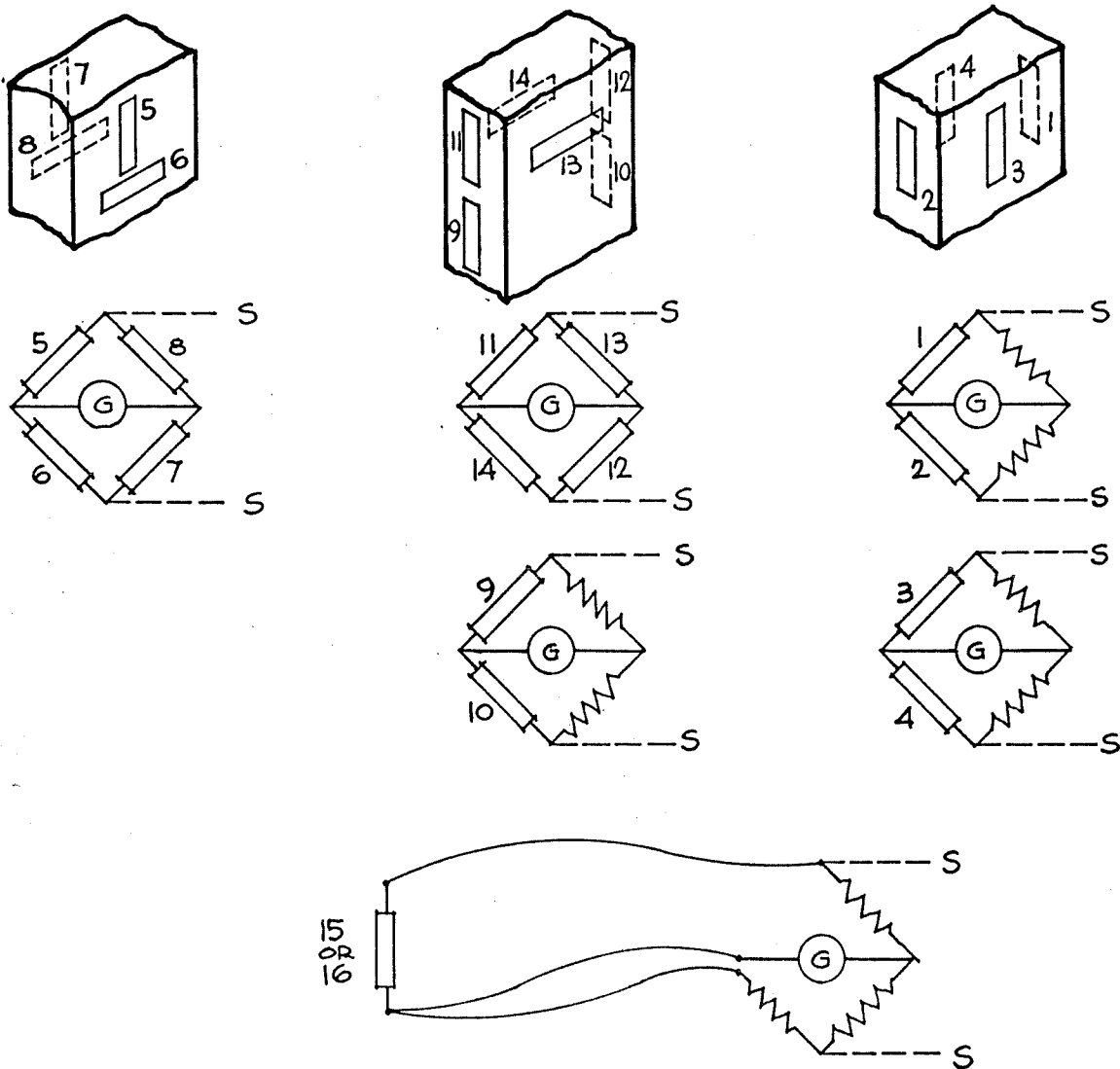


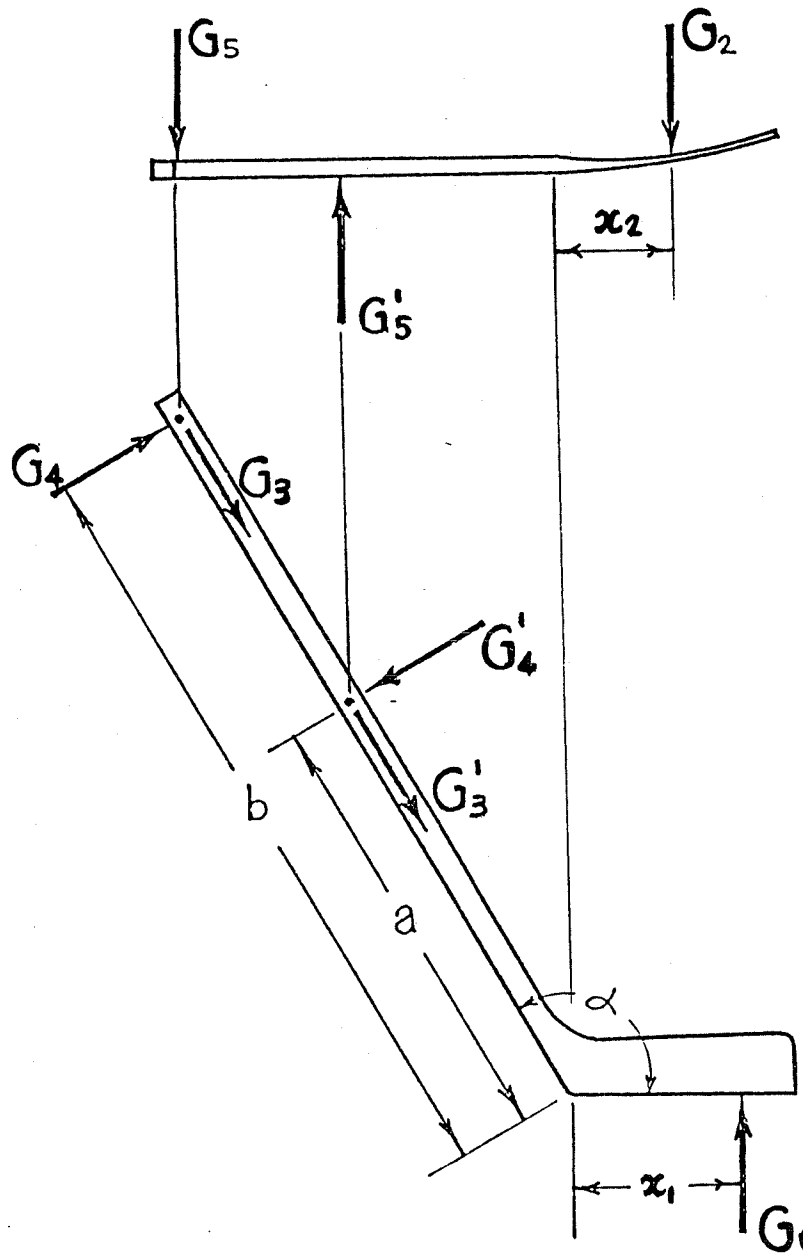
FIGURE 1 - LOCALIZATION OF THE STRAIN GAGES ON THE STICK



LEGEND

	GAGE
	BRIDGE RESISTANCE
	GALVANOMETER
	POWER SUPPLY

FIGURE 2 - ARRANGEMENT OF THE WHEATSTONE BRIDGES



NOTE: Distances a and b known.

FIGURE 3 - FORCES ACTING ON THE HOCKEY STICK

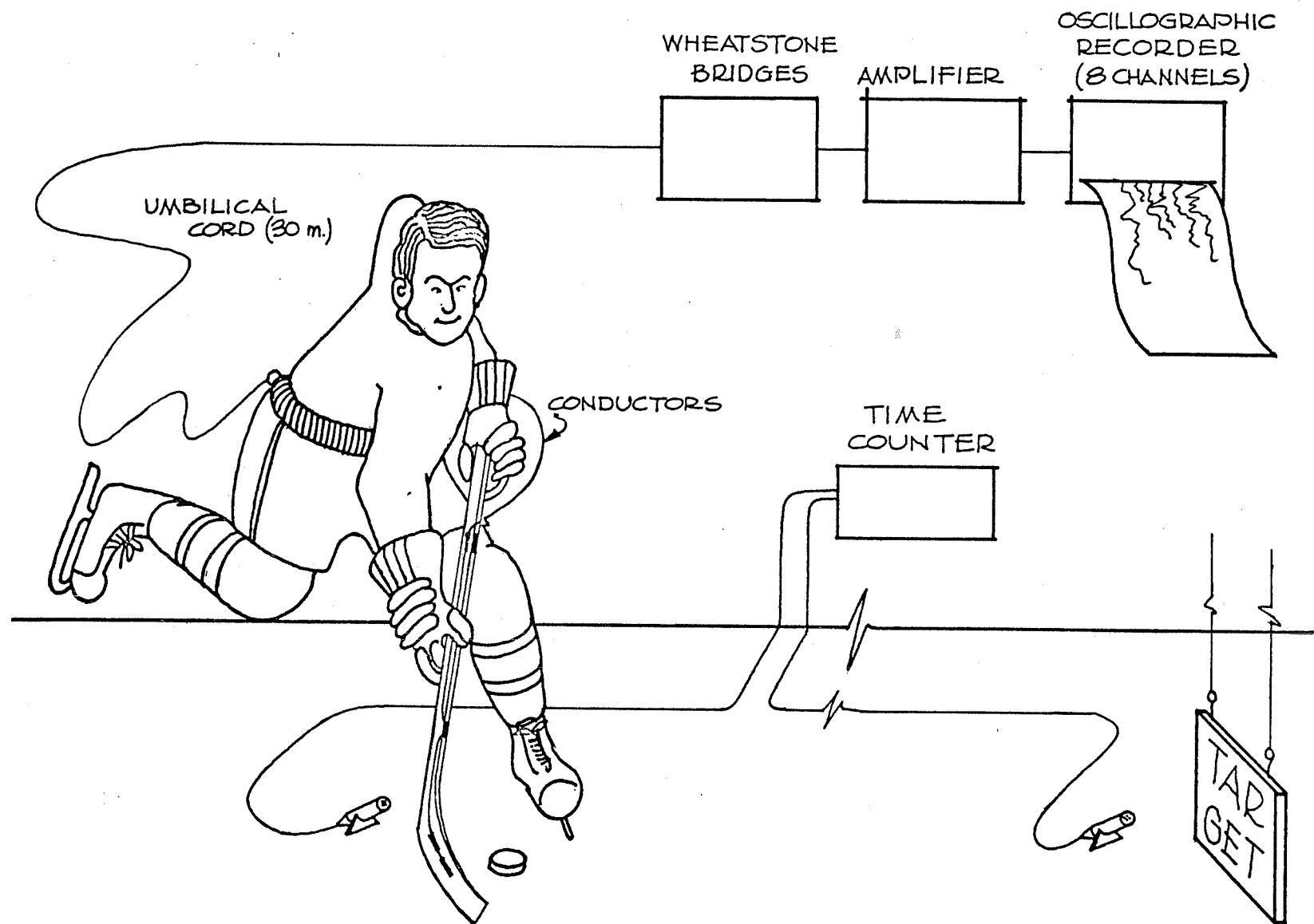


FIGURE 4 - MEASURING AND RECORDING SYSTEM

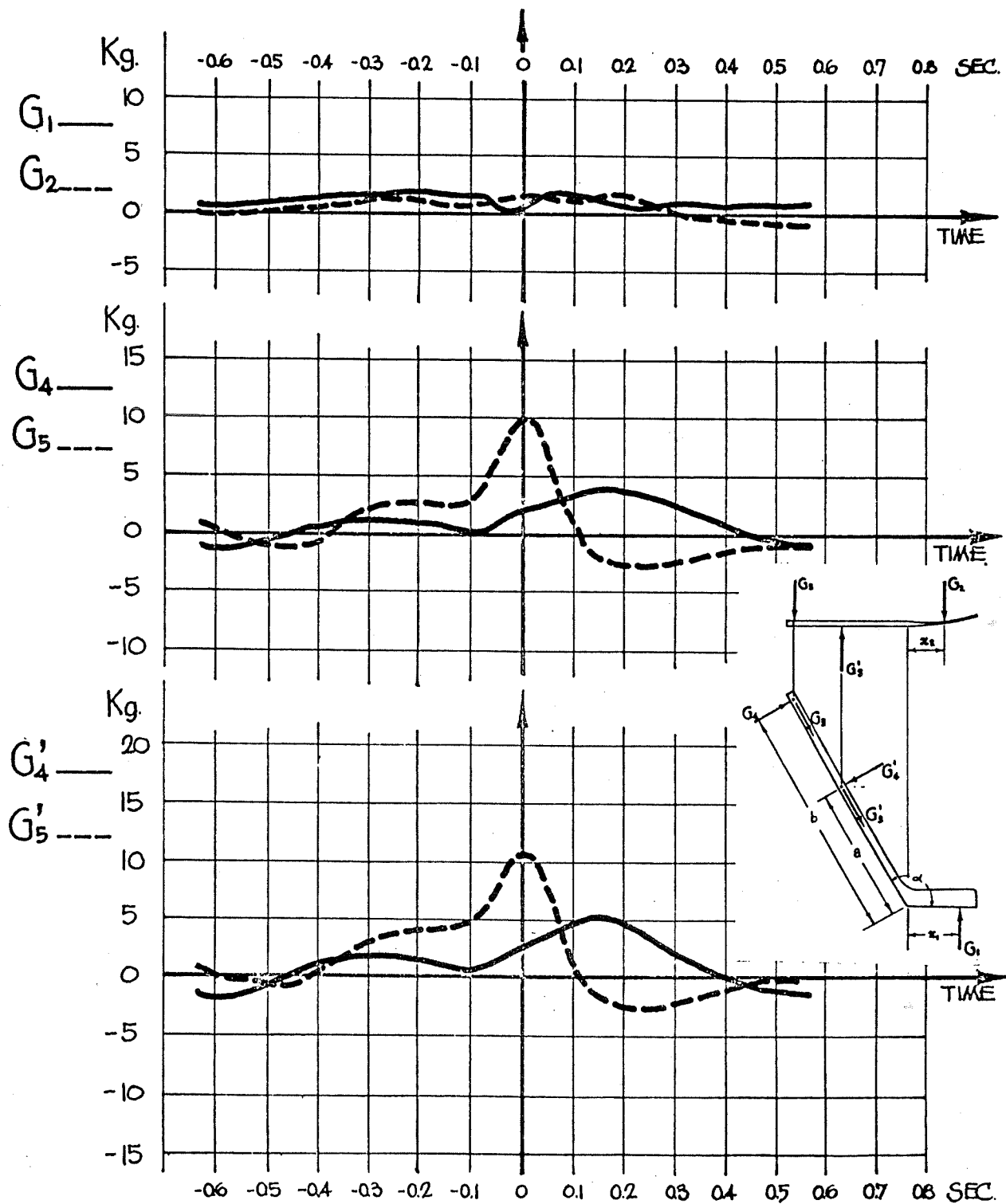


FIGURE 5 - FORCES VS TIME, SUBJECT 1, SWEEP SHOT AT REST

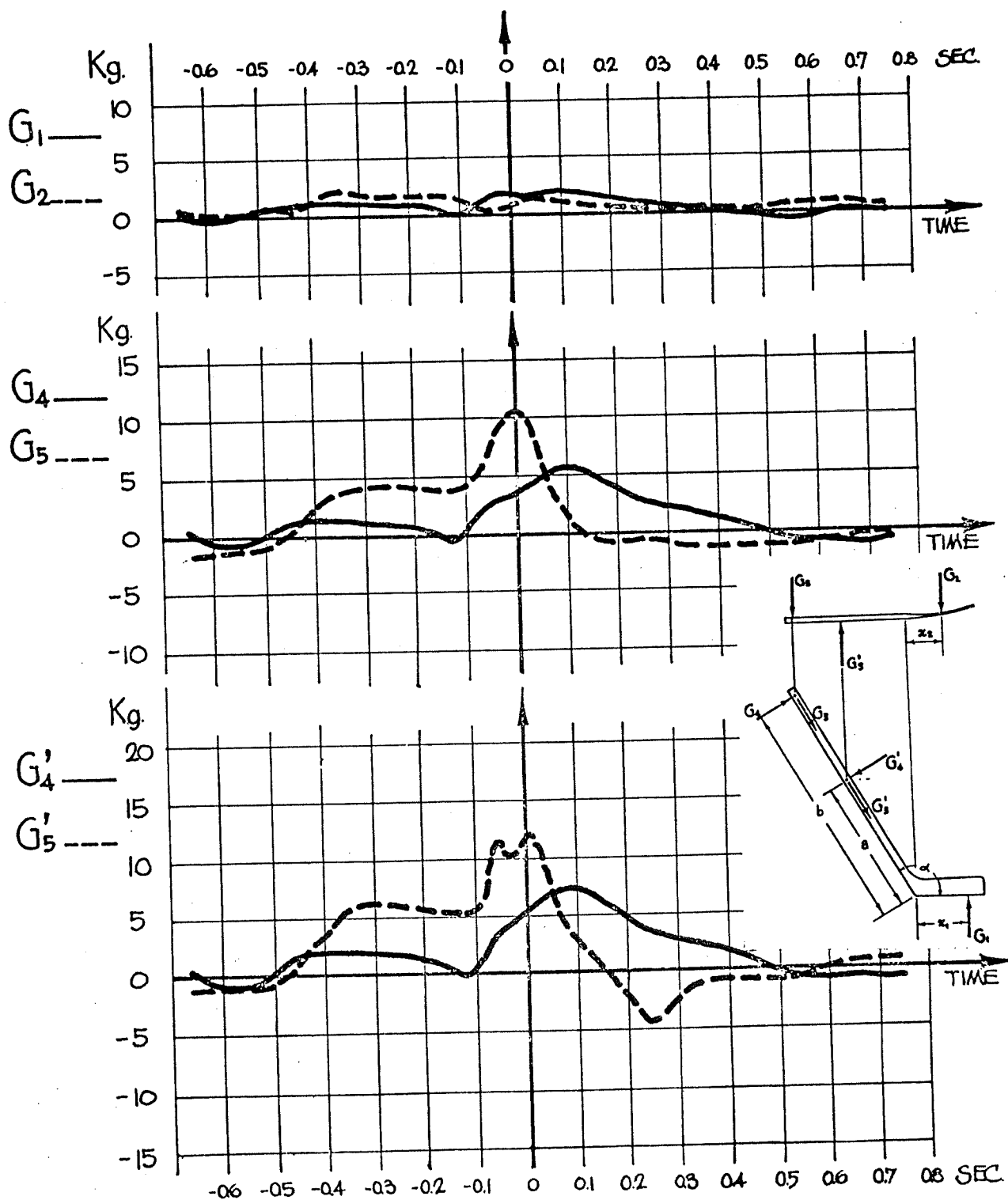


FIGURE 6 - FORCES VS TIME, SUBJECT 1, SWEEP SHOT IN MOTION

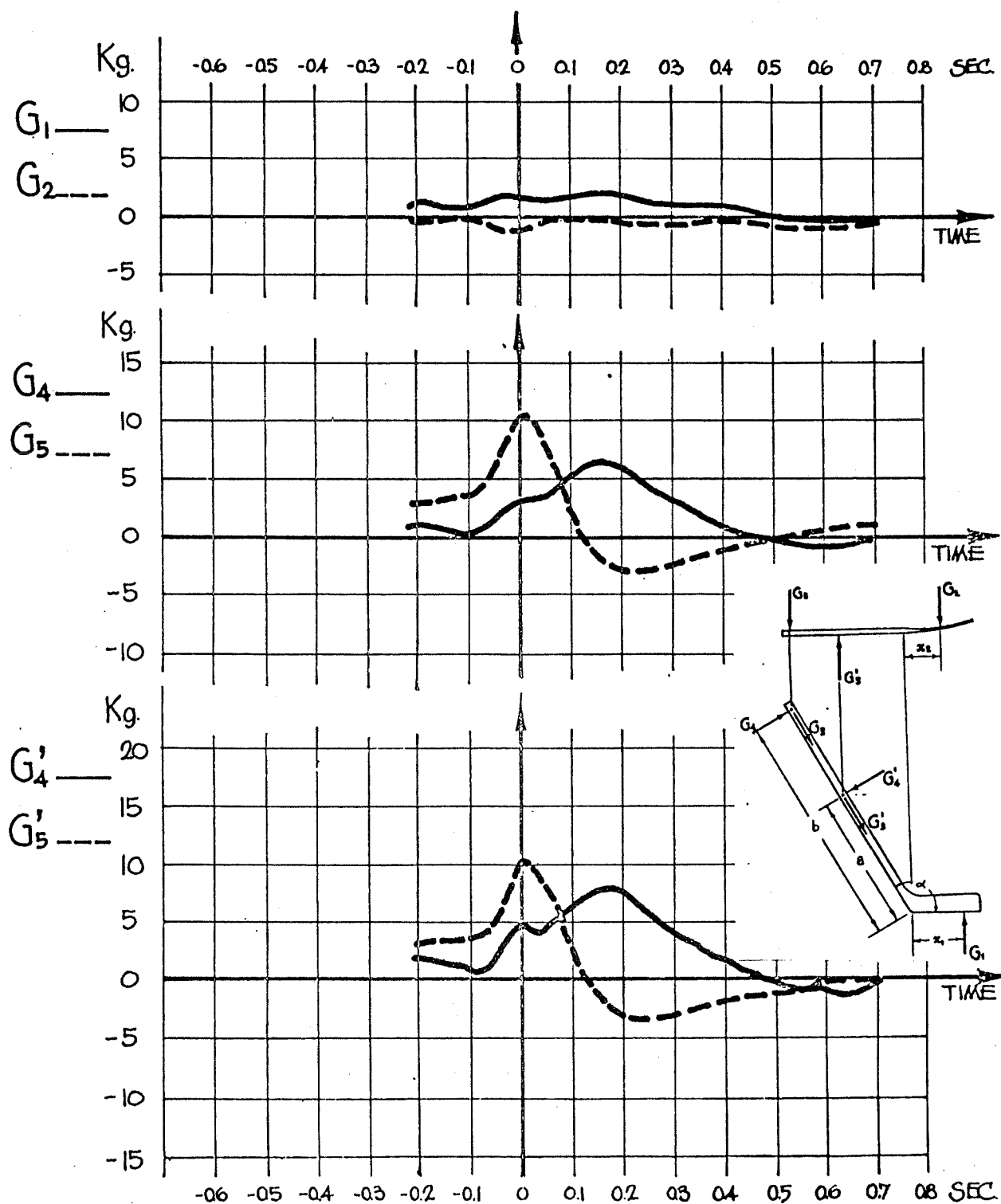


FIGURE 7 - FORCES VS TIME, SUBJECT 1, WRIST SHOT AT REST

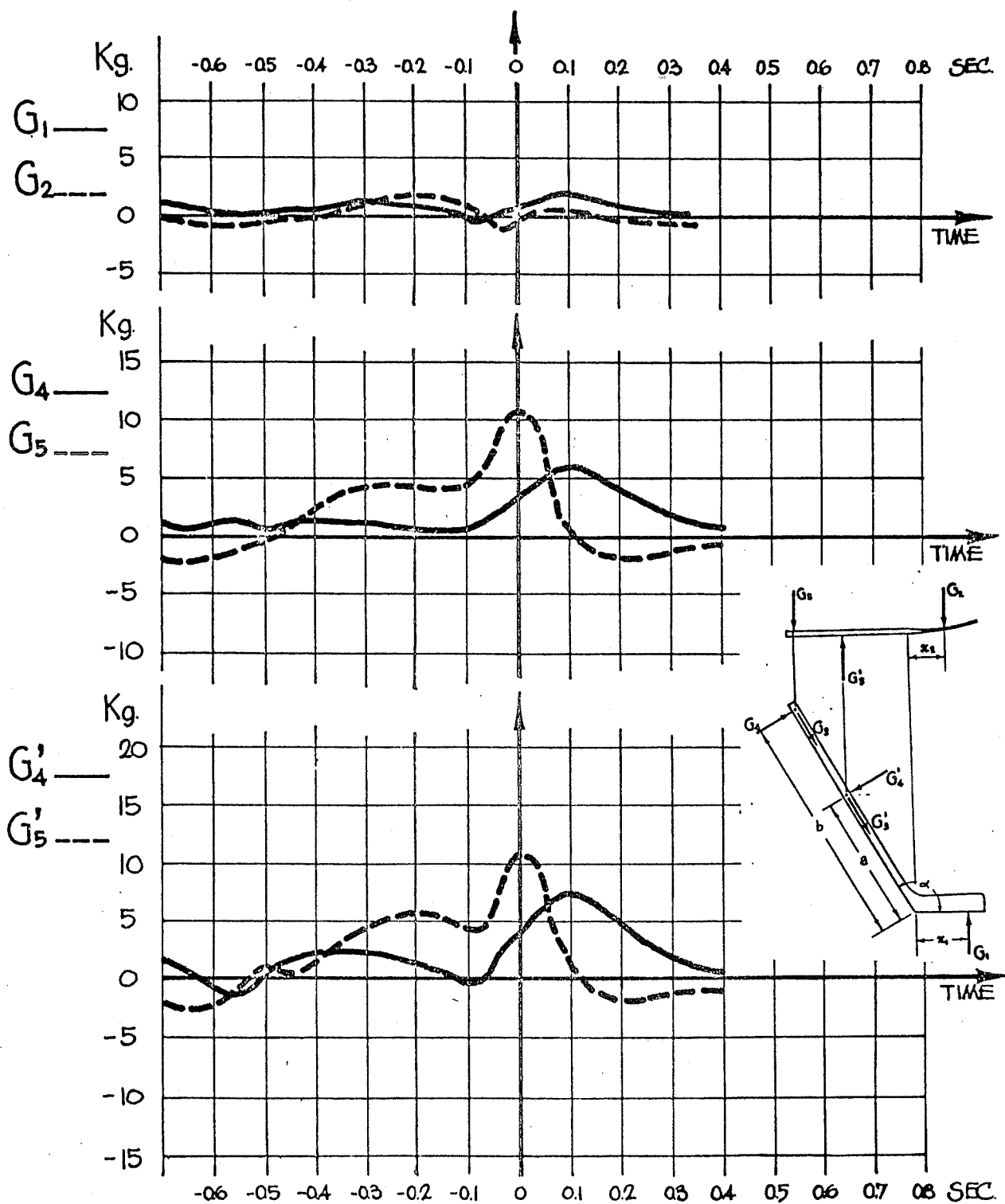


FIGURE 8 - FORCES VS TIME, SUBJECT 1, WRIST SHOT IN MOTION

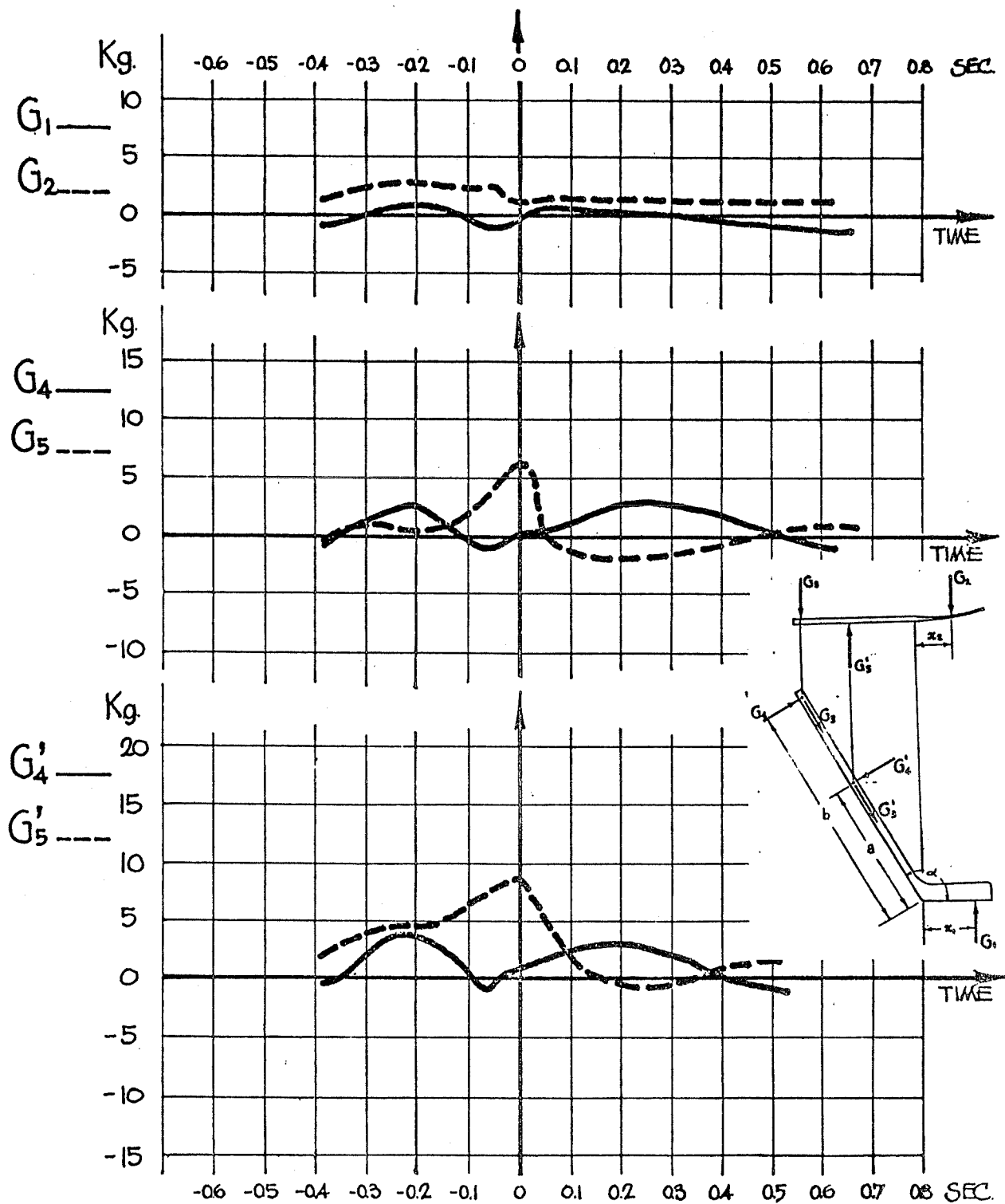


FIGURE 9 - FORCES VS TIME, SUBJECT 1, SLAP SHOT AT REST

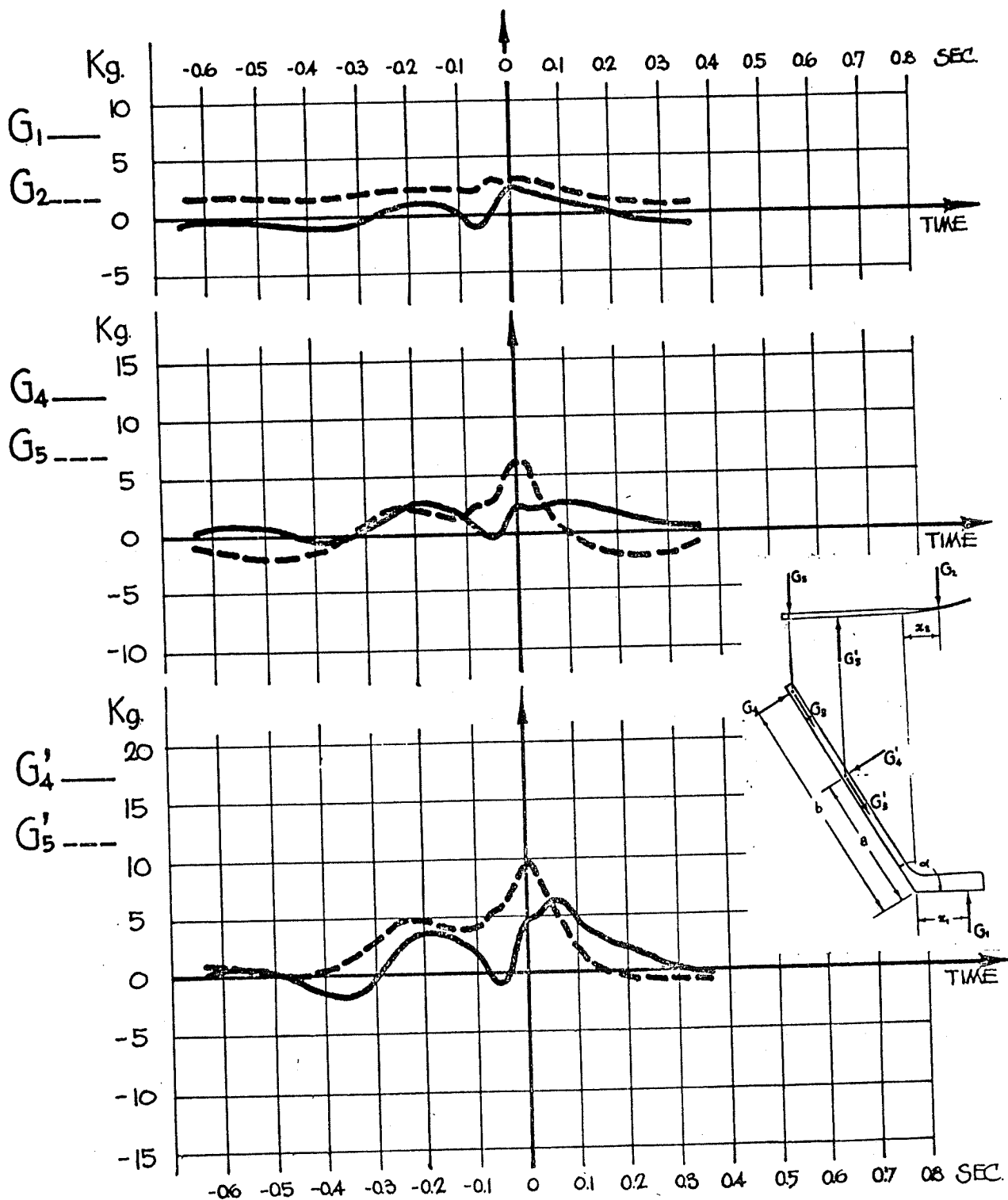


FIGURE 10 - FORCES VS TIME, SUBJECT 1, SLAP SHOT IN MOTION

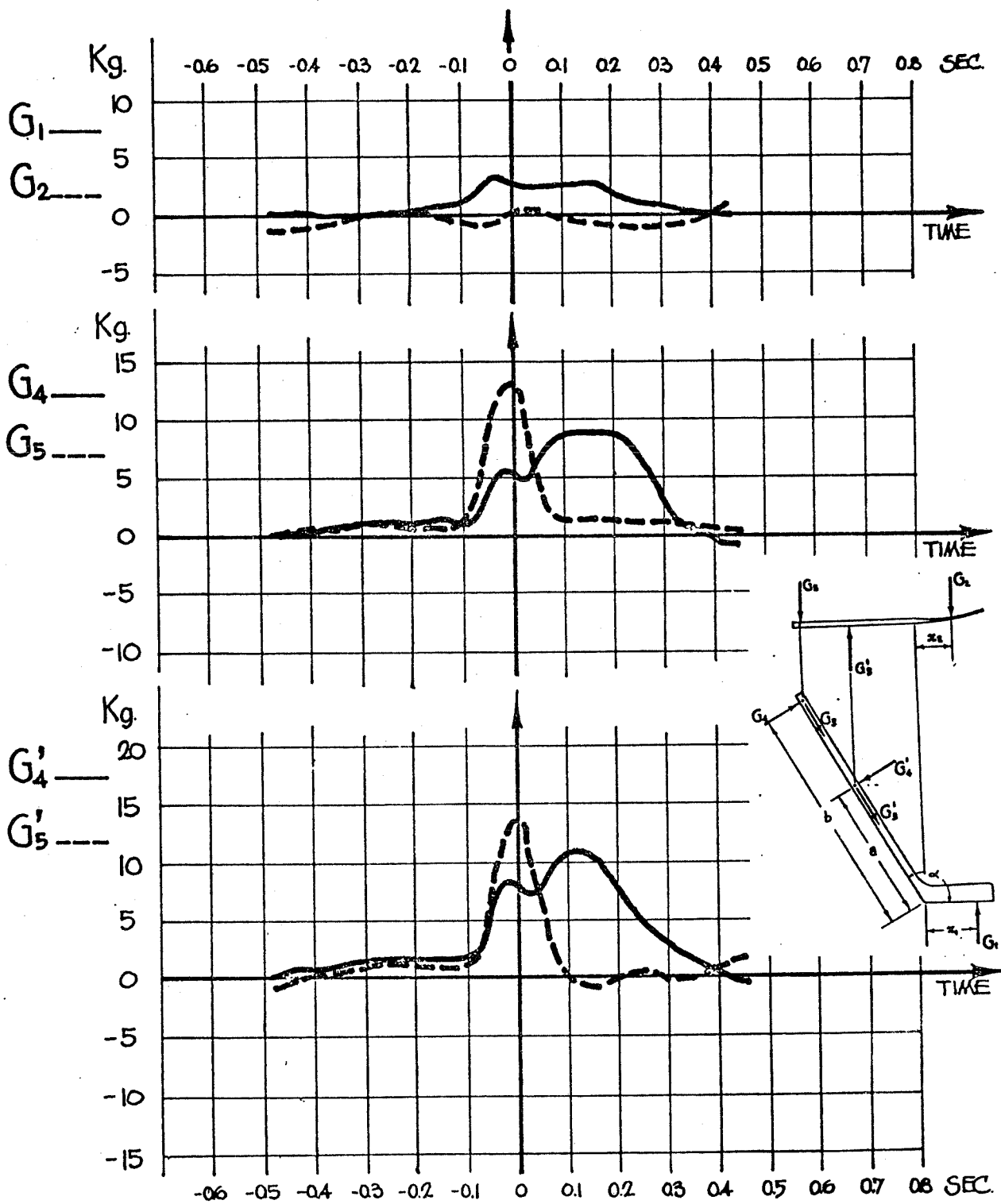


FIGURE 11 - FORCES VS TIME, SUBJECT 2, WRIST SHOT AT REST

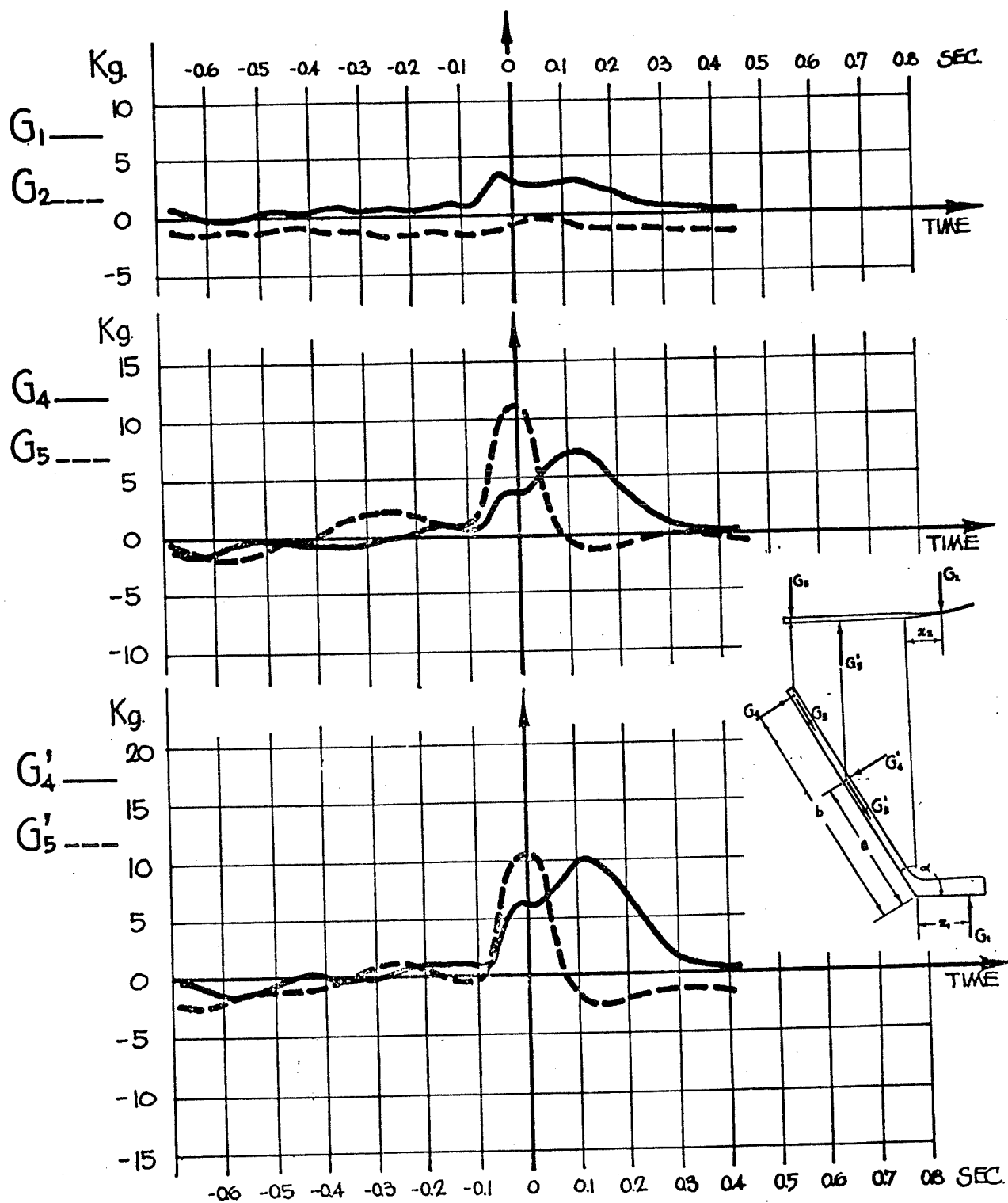


FIGURE 12 - FORCES VS TIME, SUBJECT 2, WRIST SHOT IN MOTION

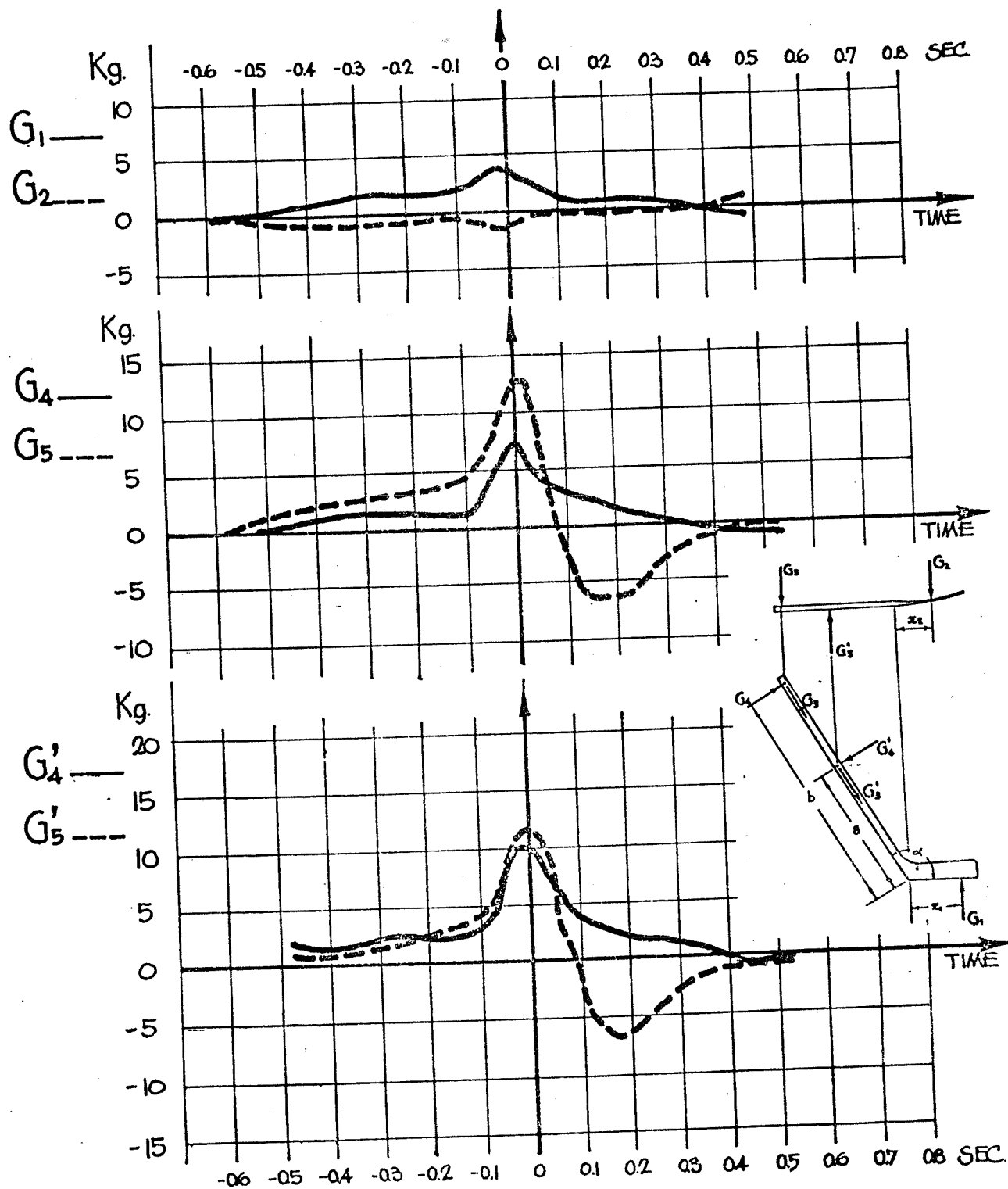


FIGURE 13 - FORCES VS TIME, SUBJECT 3, SWEEP SHOT AT REST

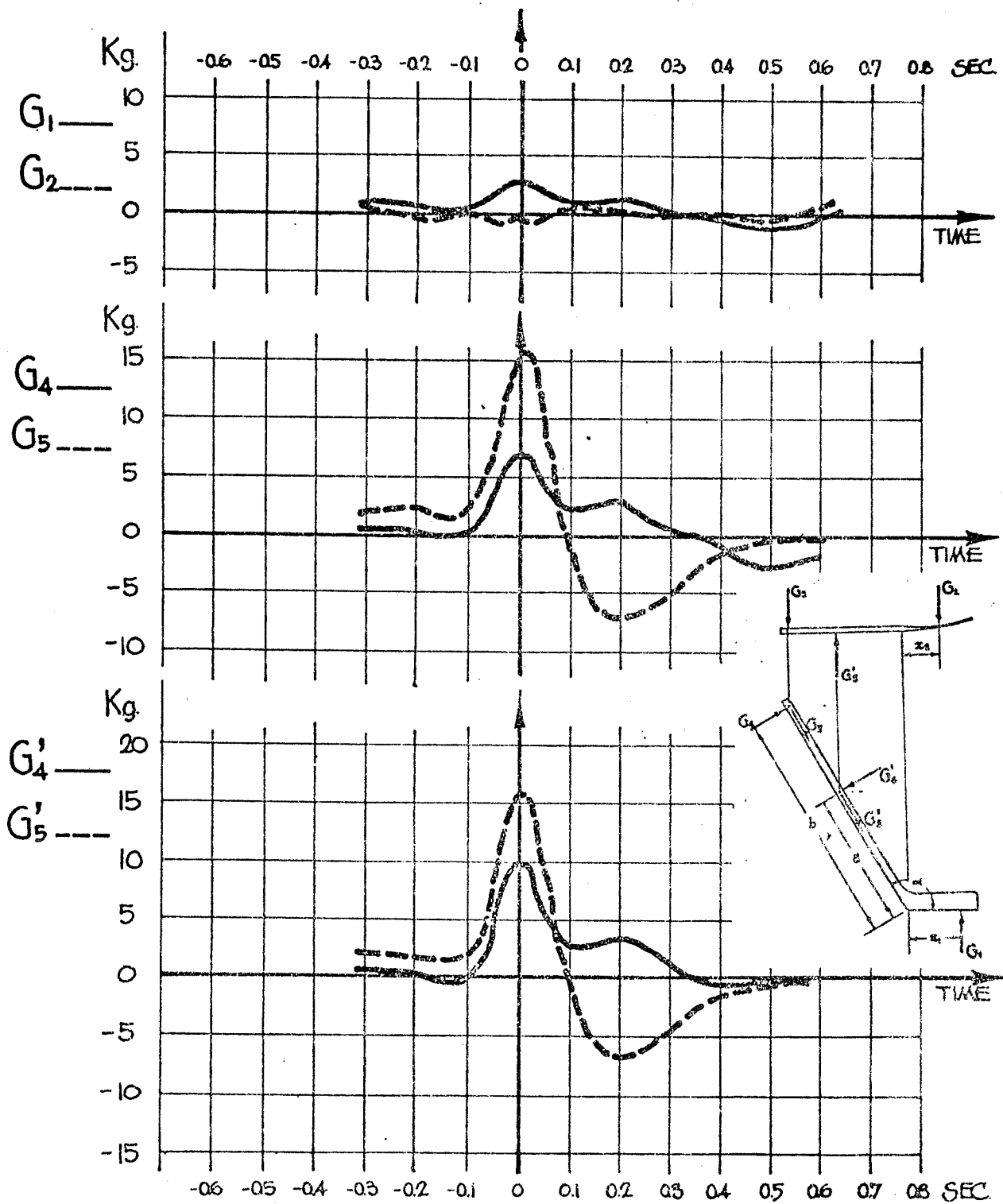


FIGURE 14 - FORCES VS TIME, SUBJECT 3, SWEEP SHOT IN MOTION

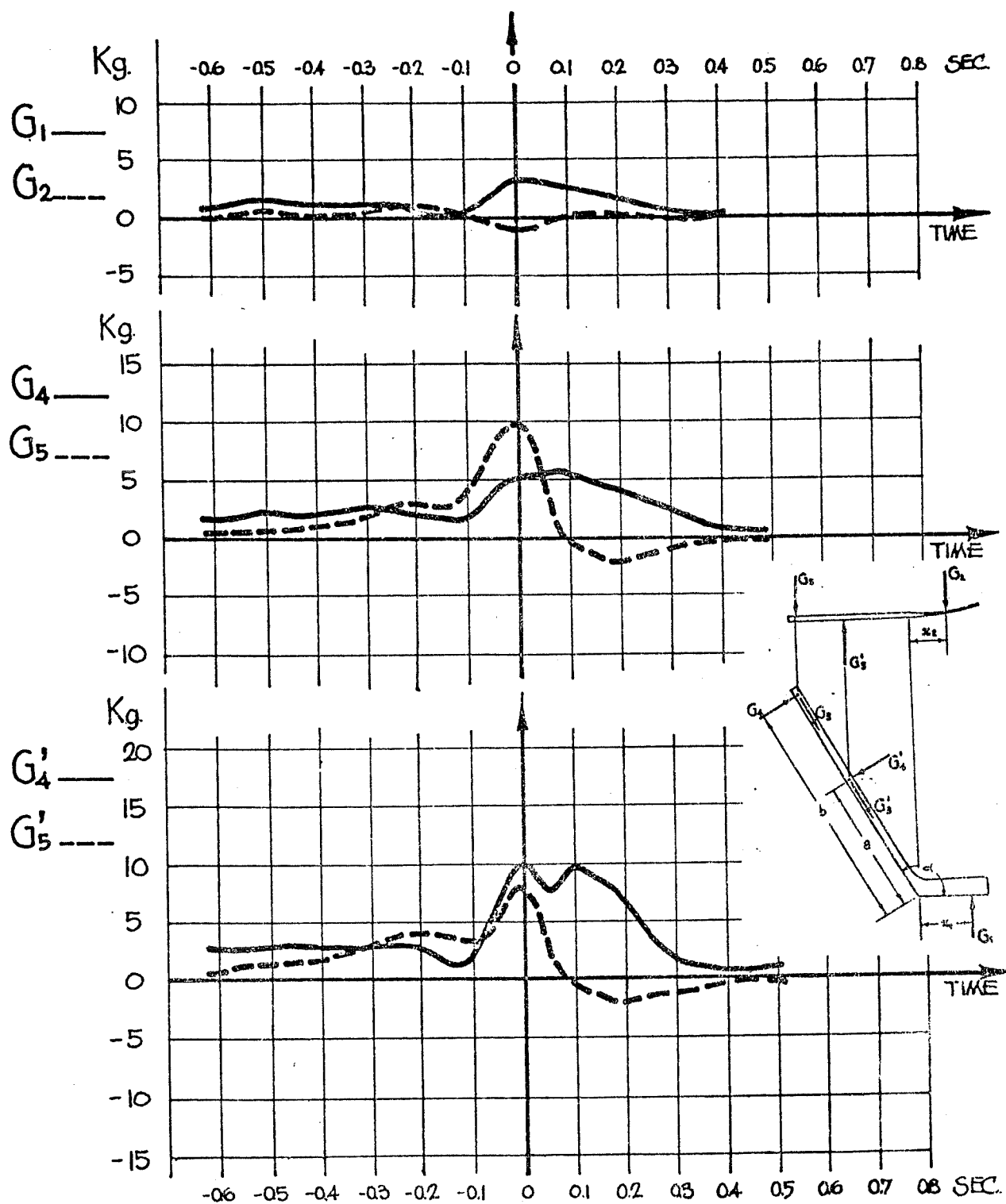


FIGURE 15 - FORCES VS TIME, SUBJECT 4, SWEEP SHOT AT REST

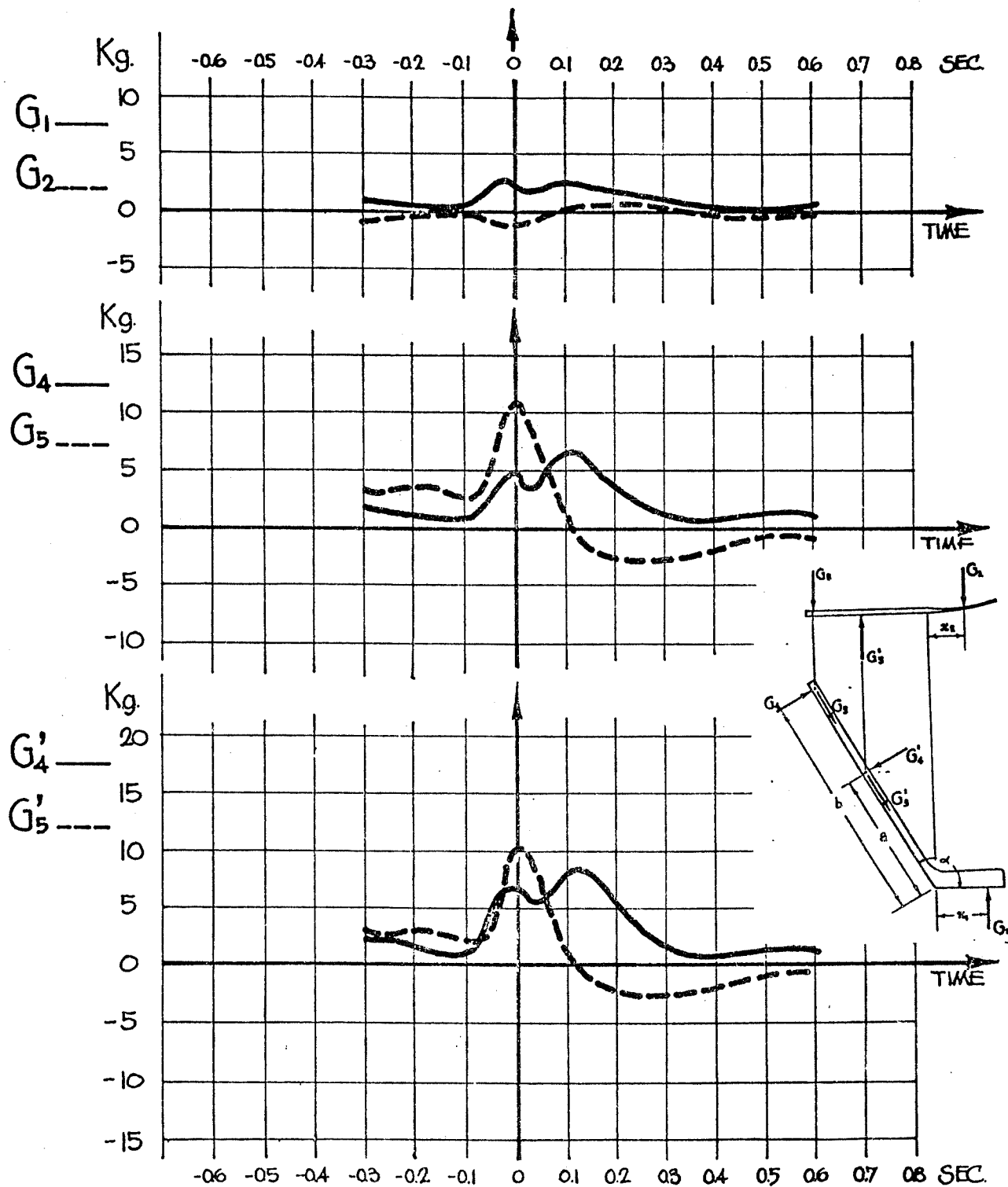


FIGURE 16 - FORCES VS TIME, SUBJECT 4, SWEEP SHOT IN MOTION (FIRST)

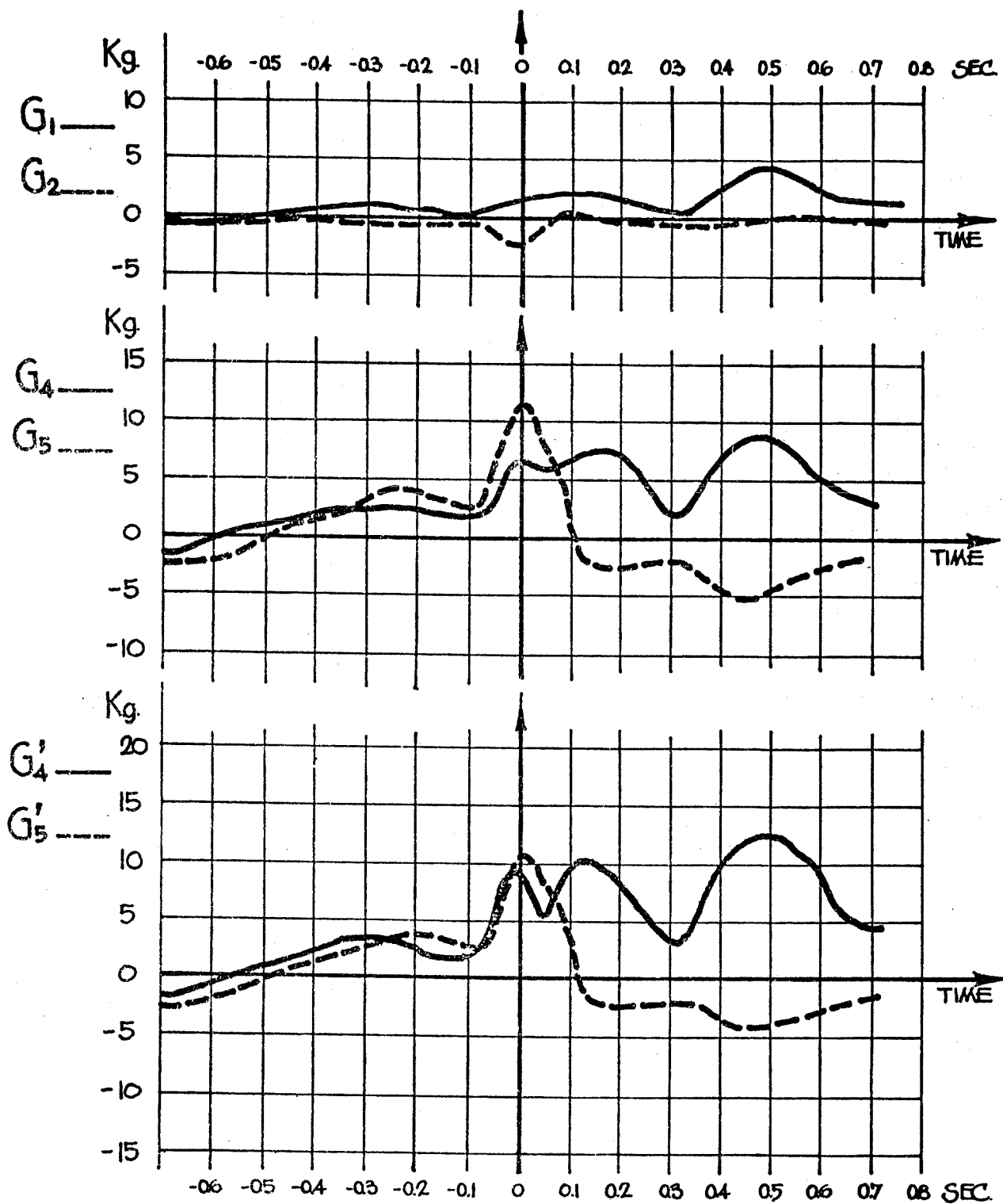


FIGURE 17 - FORCE VS TIME, SUBJECT 4, SWEEP SHOT IN MOTION (SECOND)

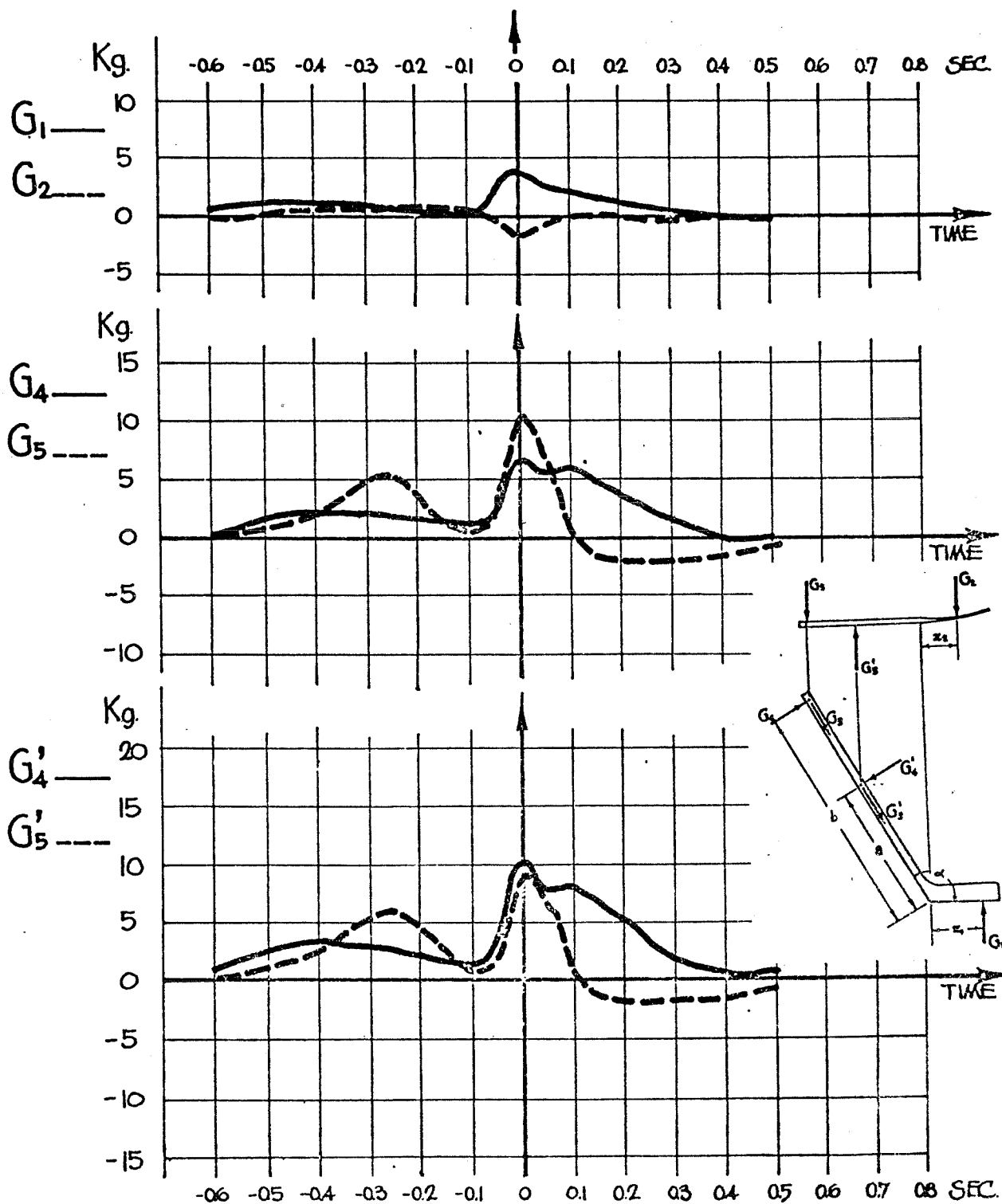


FIGURE 18 - FORCES VS TIME, SUBJECT 4, HALF SLAP SHOT AT REST

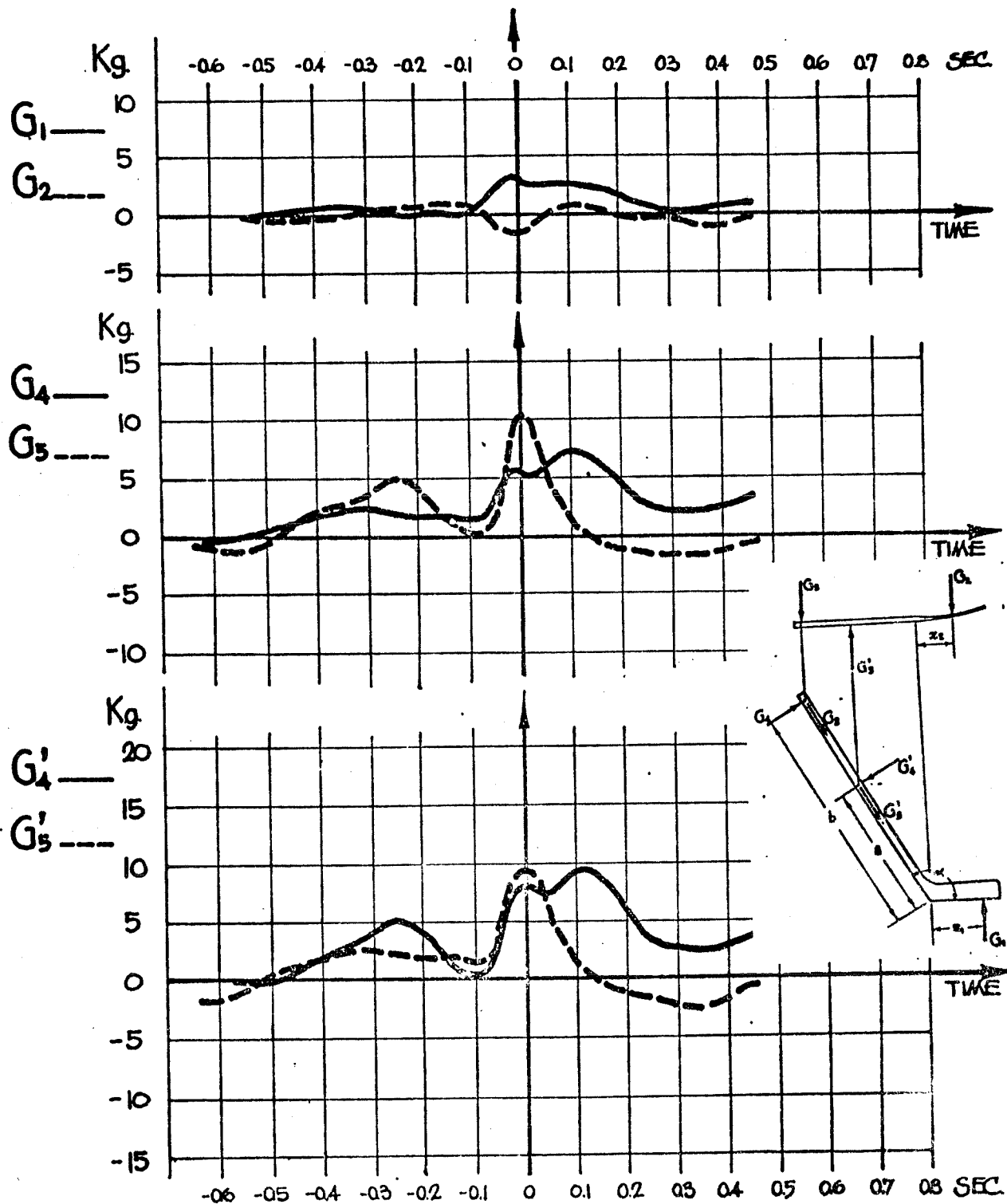


FIGURE 19 - FORCES VS TIME, SUBJECT 4, HALF SLAP SHOT IN MOTION

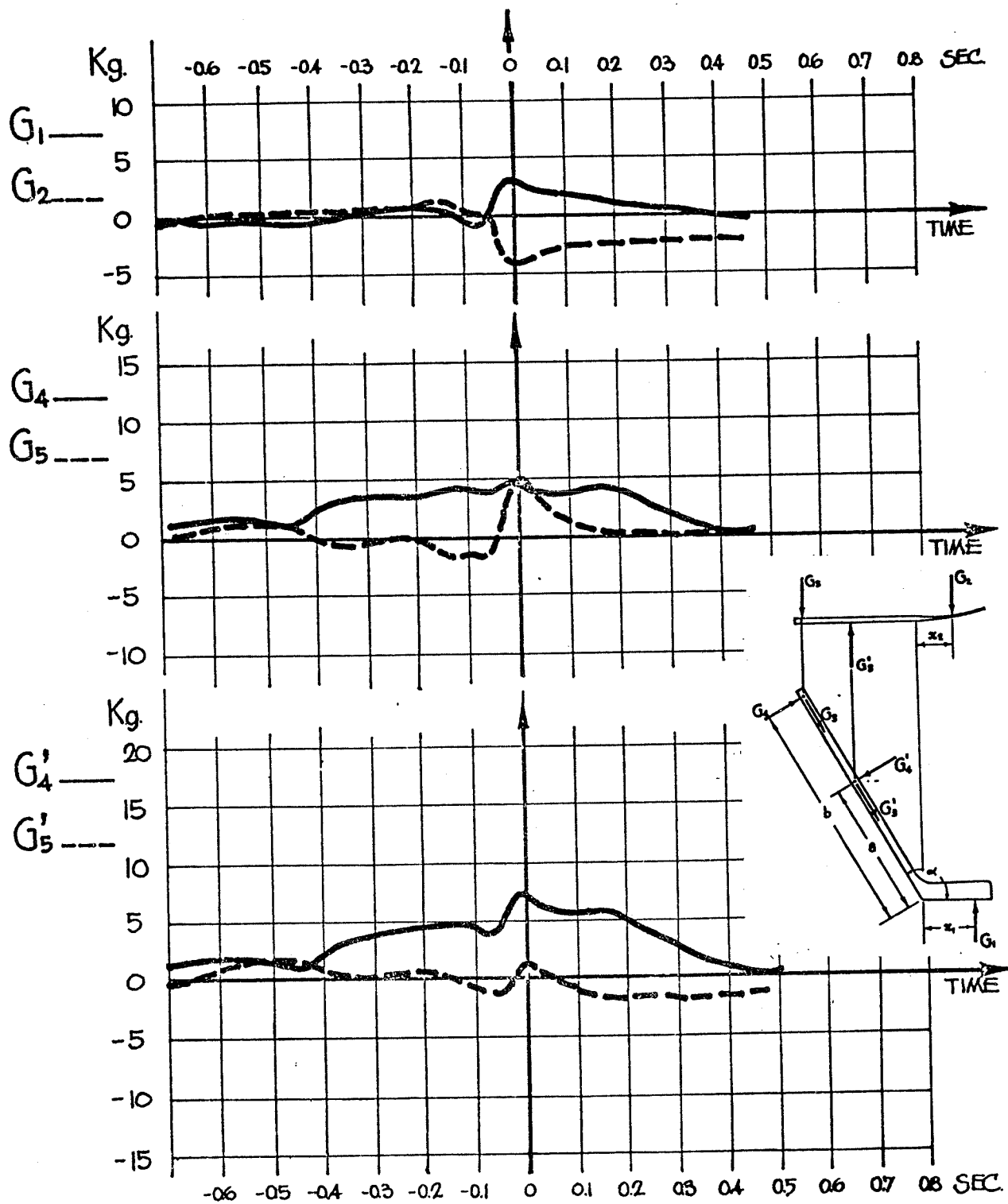


FIGURE 20 - FORCES VS TIME, SUBJECT 5, SLAP SHOT IN MOTION (FIRST)

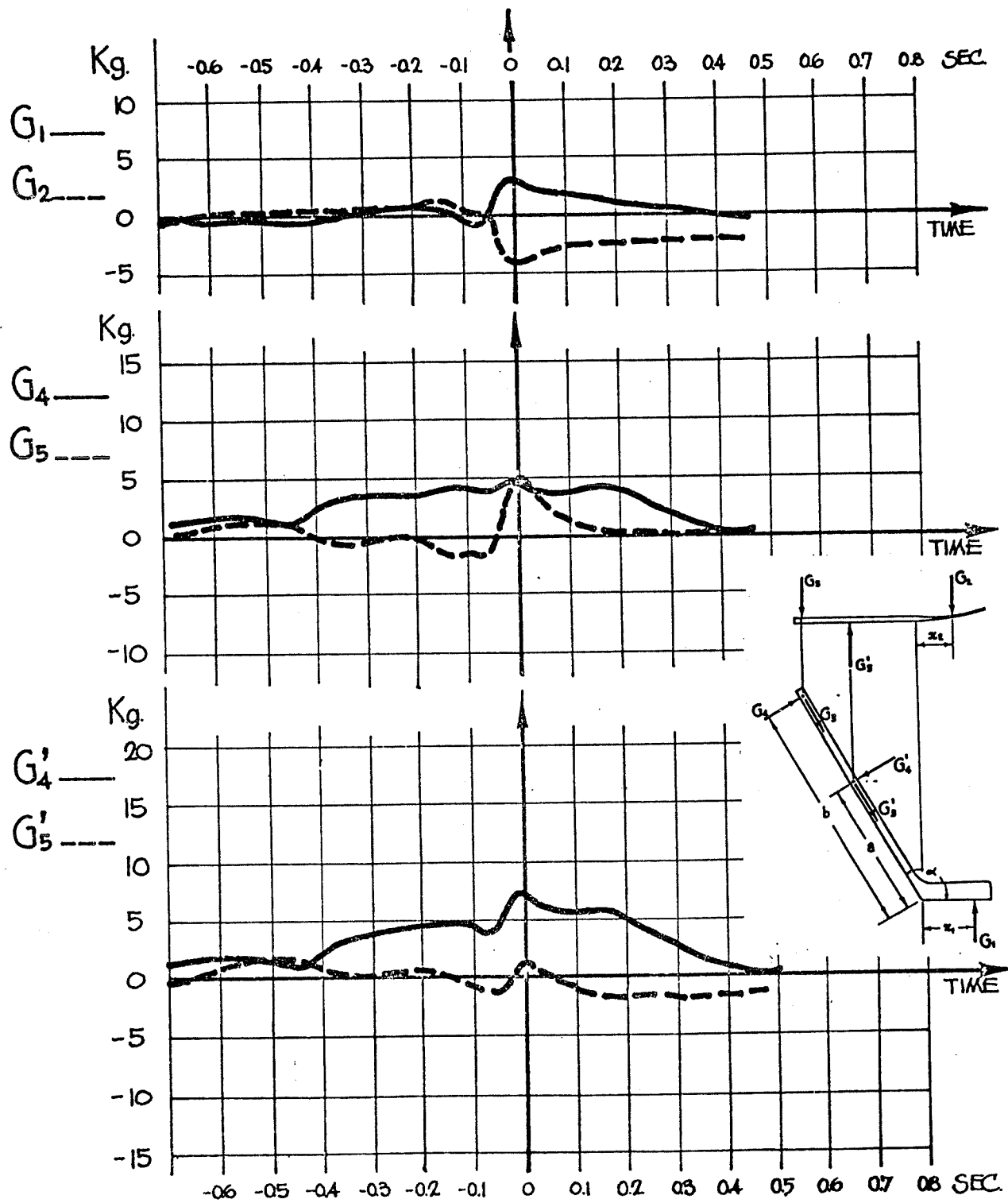


FIGURE 20 - FORCES VS TIME, SUBJECT 5, SLAP SHOT IN MOTION (FIRST)

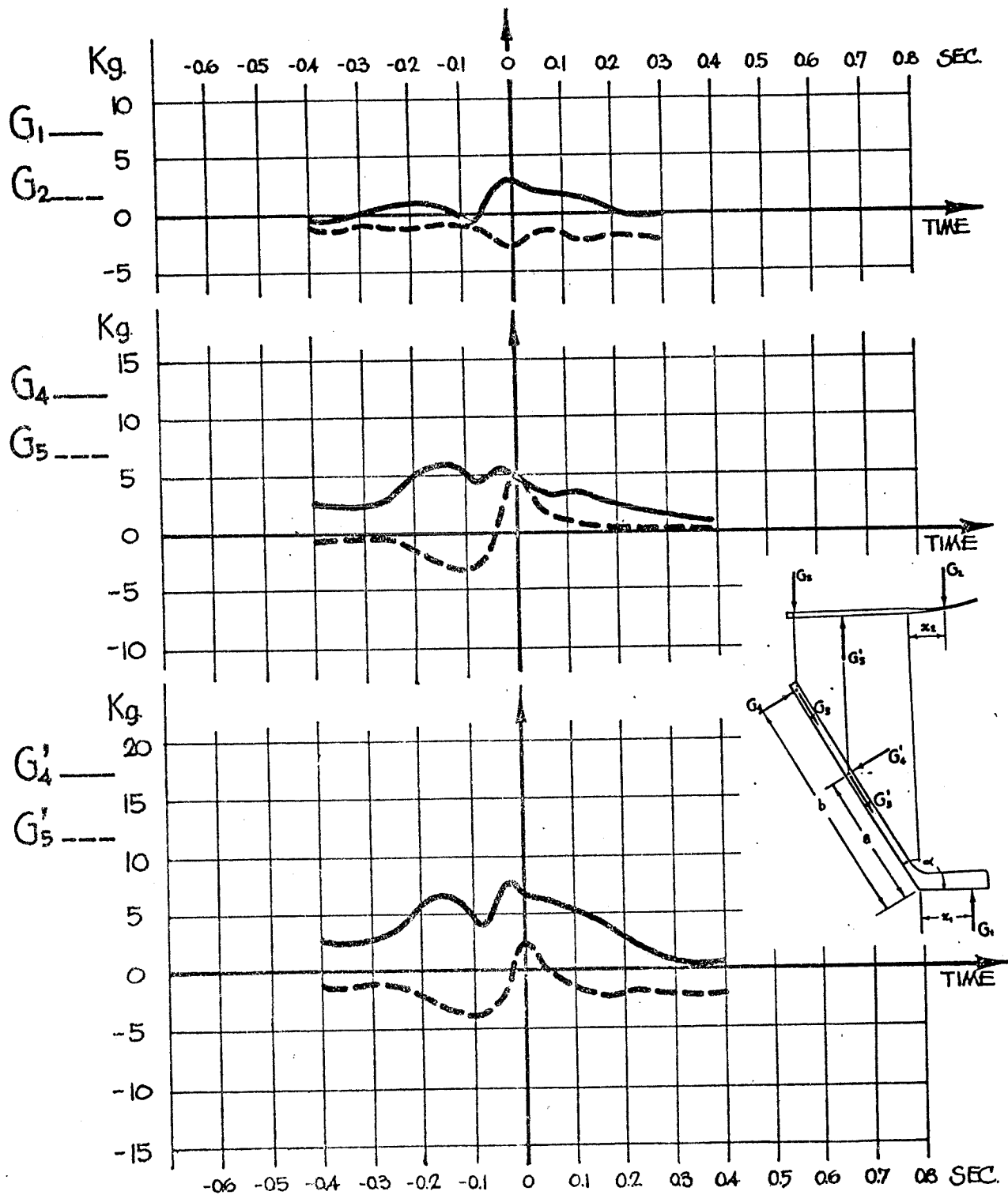


FIGURE 21 - FORCES VS TIME, SUBJECT 5, SLAP SHOT IN MOTION . (SECOND)

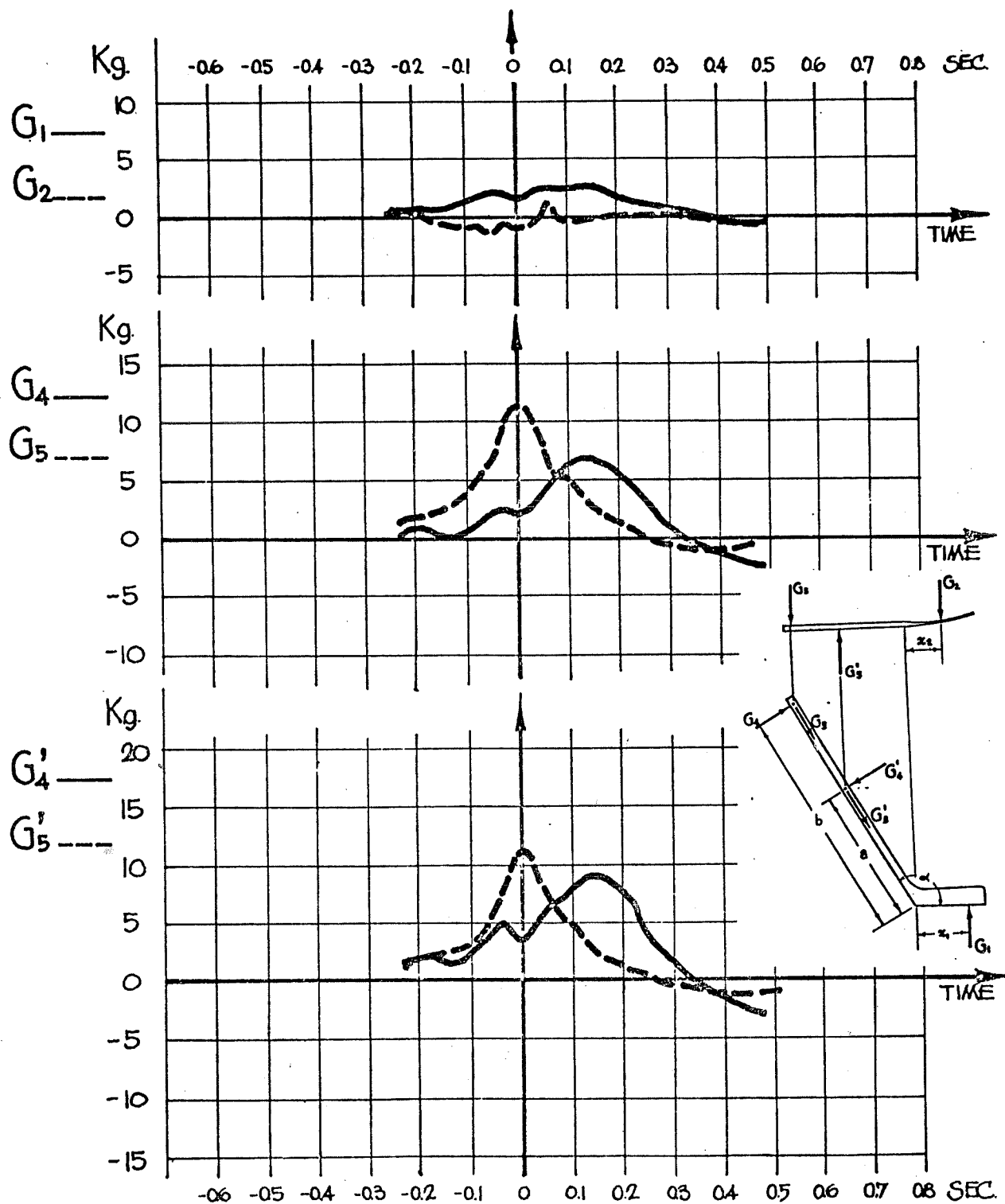


FIGURE 22 - FORCES VS TIME, SUBJECT 6, WRIST SHOT AT REST (FIRST)

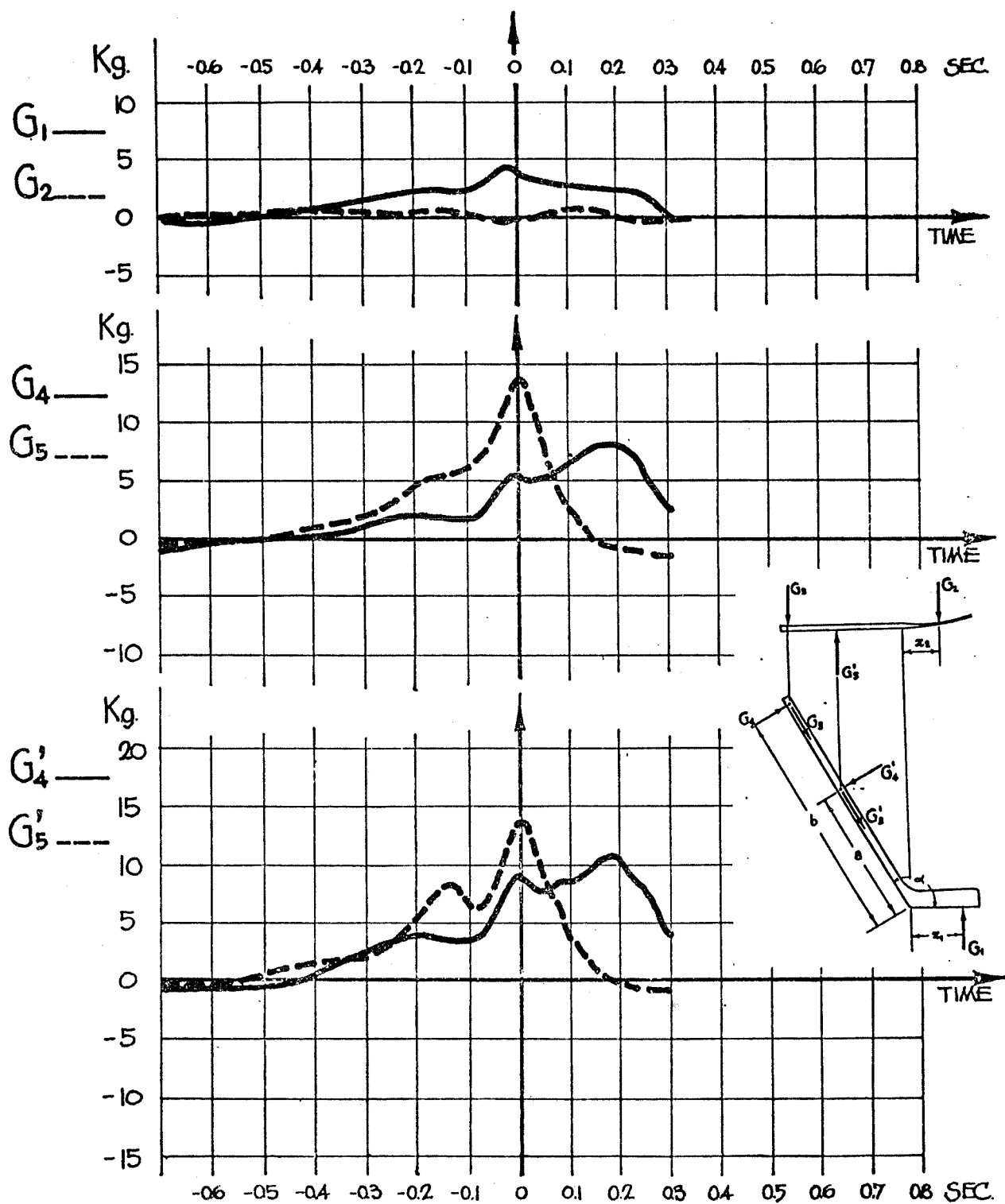


FIGURE 23 - FORCES VS TIME, SUBJECT 6, WRIST SHOT AT REST (SECOND)

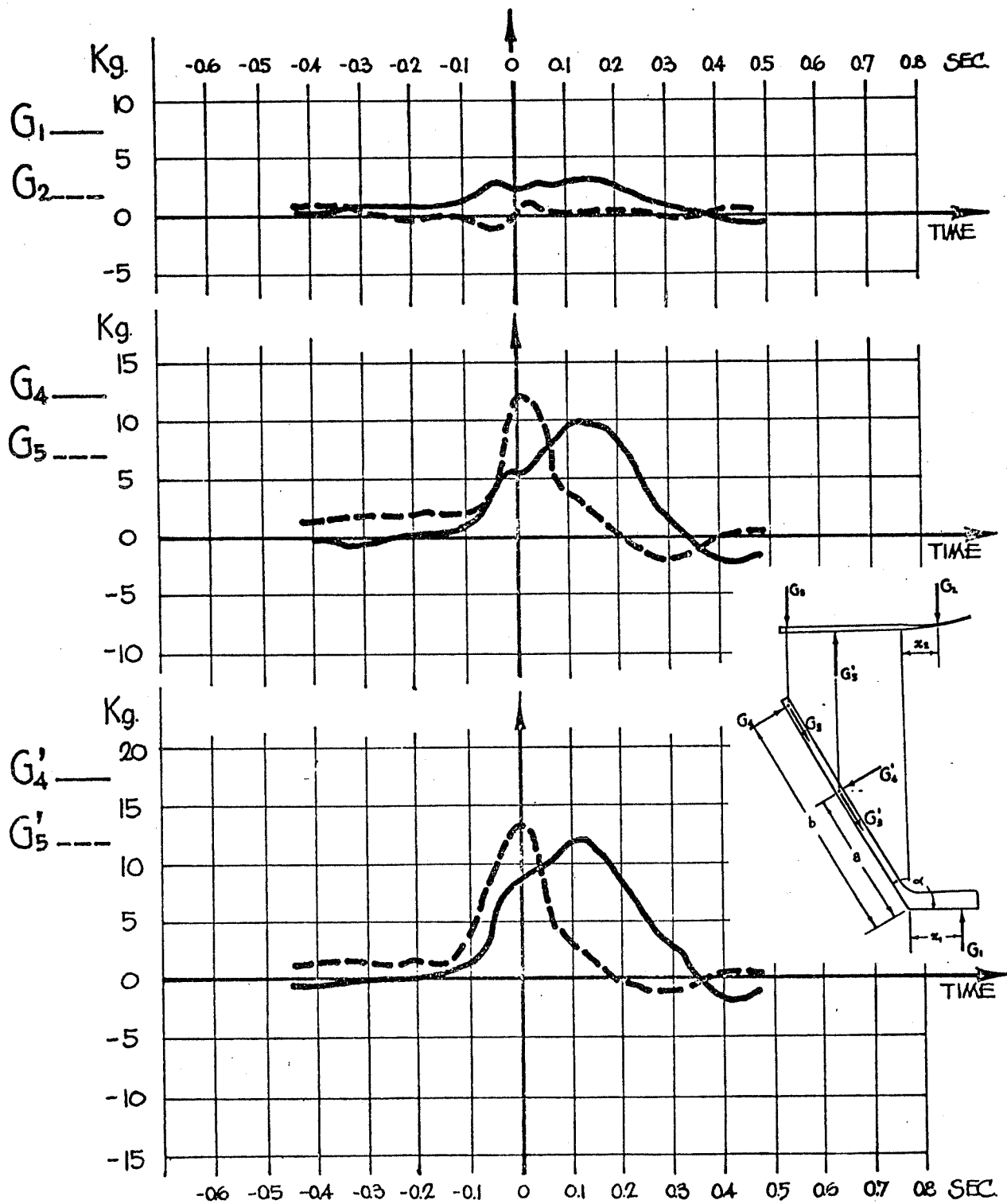


FIGURE 24 - FORCES VS TIME, SUBJECT 6, WRIST SHOT IN MOTION (FIRST)

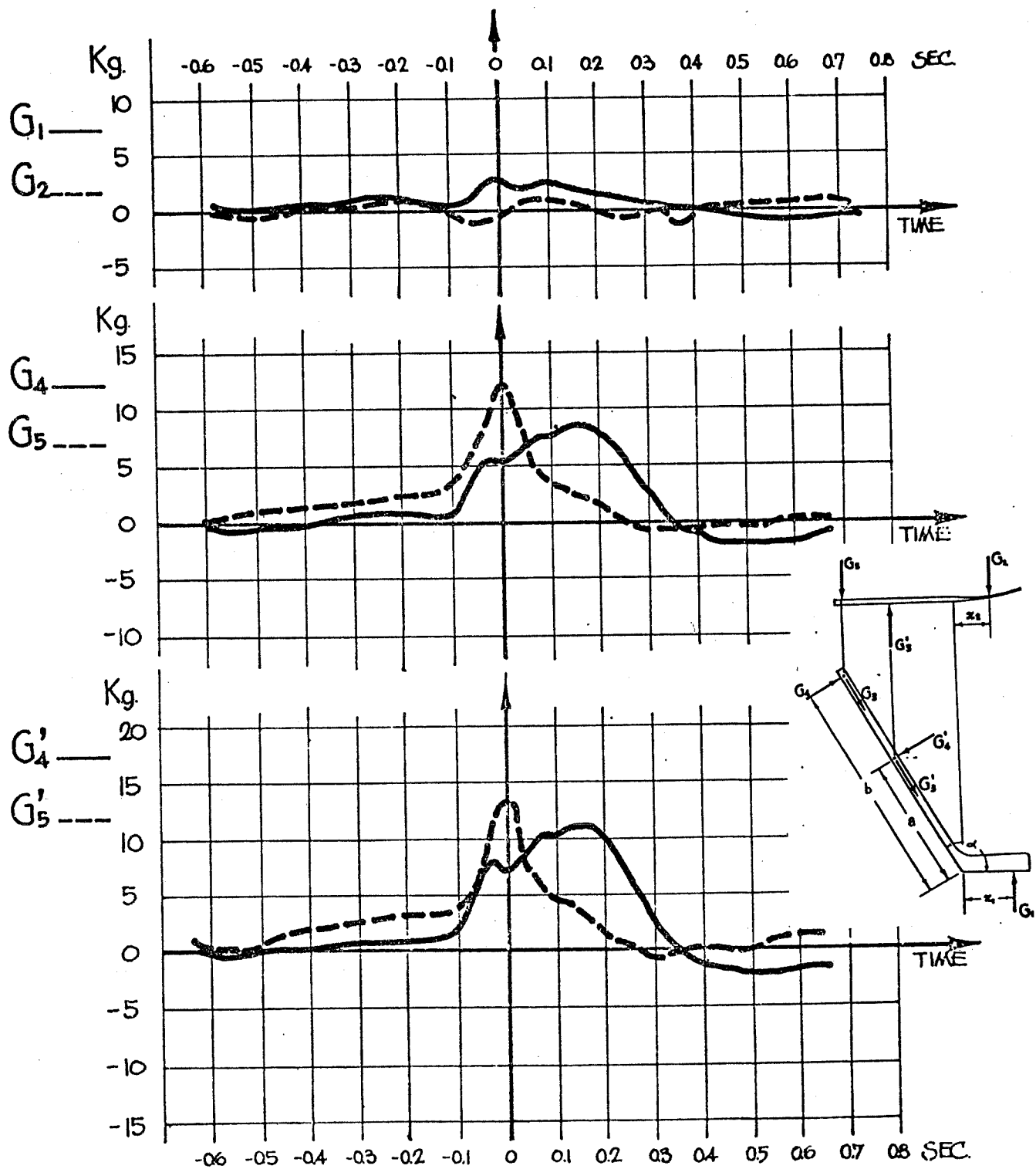


FIGURE 25 - FORCES VS TIME, SUBJECT 6, WRIST SHOT IN MOTION (SECOND)

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