DEPARTMENT OF MINERALS AND ENERGY

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Record 1974/63

SLINGRAM MODEL TESTS

by

K. Duckworth

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ILLUSTRATIONS

SUMMARY

Slingram model tests were made by the Darwin Uranium Group of the Bureau of Mineral Resources (BMR) to assist in the interpretation of field results being obtained by the Group.

The equipment used was the Slingram field compensator plus miniature receiving and transmitting coils and a signal generator. Models used were conducting sheets and boxes and, for magnetic bodies, steel grit. Frequency used was 1760 Hz, the same as used in the field. The scale was 18 inches coil separation in the model tests to 200 ft coil separation in the field, that is 1:133 1/3.

The results proved useful in revealing the profiles to be expected over various structures. The most interesting results are the profiles over magnetic bodies and the relation shown to exist between the geometry of a body and the coil spacing. This relation was used to develop a depth probe system.

Except for the depth probe, the model tests results were qualitative. Suggestions are made for improving the flexibility of the modelling and to establish a basis for quantitative work.

1. INTRODUCTION

When work began in 1964 on the model tests described in this report little had been published on the theory of electromagnetic methods of prospecting or on the interpretation of results. Slingram equipment was being used extensively by the Darwin Uranium Group of the Bureau of Mineral Resources (BMR) and modelling offered some opportunity to investigate the results being obtained. The model tests were carried out by the Darwin Uranium Group and were biased towards elucidating the particular problems being encountered in the field. The conductive structures expected and therefore modelled were mainly tabular bodies with high dips and limited strike lengths, and horizontal bodies. The aim of the model tests was to simulate geological conditions in the laboratory and thereby obtain a basis for qualitative interpretation of field results. Inevitably it was realized that the scope of the model work should not be limited by particular field problems and suggestions are made later for improving the flexibility of the modelling and to establish a basis for quantitative work.

The equipment used in the model tests was the Slingram field compensator connected to miniature transmitting and receiving coils; the transmitting coil was fed from a laboratory signal generator. The frequency used was 1760 Hz, the same as that used in the field. The coil spacing was 18 inches; the usual coil spacing in the field was 200 ft, so that the scale of the model tests was $1:133\frac{1}{3}$.

The model tests were carried out intermittently between field seasons over a period of four years; they were initiated by J. Ashley and continued by K. Duckworth. The results proved useful in aiding the interpretation of field results and it seems probable that the usefulness can be extended by refinements which are suggested later.

During the model tests an electromagnetic depth-sounding method using variable coil spacing was developed in the laboratory and tested in the field.

2. EQUIPMENT

The Slingram electromagnetic equipment is a moving source - moving receiver type using two horizontal coplanar coils at fixed spacing, and normally carried in line astern along traverses. The Slingram equipment uses a compensating system which balances a recieved signal against a reference signal supplied by cable from a small feeding coil mounted coaxially with the transmitting coil. Results are derived as an in-phase or real component, R, and an out-of-phase or quadrature or imaginary component, I. Calibration depends upon control of the magnitude of the reference signal; variable resistors are provided in the compensator for this control. When calibrated for a non-conducting environment, the settings are R = 100% and I = 0%. This corresponds to the received signal being caused by the primary field alone with no consequent phase lag.

In the model tests the transmitting coil was fed by an oscillator through a power amplifier. The oscillator was a normal laboratory signal generator producing a sine-wave output, and was tunable over a wide range of frequencies; frequency used was 1760 Hz. The power amplifier was a normal audio public address amplifier. It was necessary to amplify the oscillator output to get adequate sensitivity in the compensating system.

The compensator was the unit used in the field equipment with minor modifications to the calibrating system to suit the different signal strengths used in the model tests. A cathode-ray oscilloscope was substituted for the normal earphone output and proved to be a better means of detecting the null point. Reproducibility of readings was within 0.2%.

The transmitting coil was constructed of fine copper wire wound on a half-inch diameter cylindrical former; it was wound with tappings provided every 400 turns and its length was about one inch. The feeding coil was wound on a former with a half-inch inner diameter. This permitted it to slide coaxially in relation to the transmitting coil. A soft iron core was fixed inside the transmitting coil former. By adjustment of the core position the output signal strength was brought to a maximum and then the feeding coil was adjusted until the reference signal was in the magnitude range which the compensation calibration system could use.

The receiving coil was a double coaxial coil salvaged from a radio chassis, and was a pair of matched coils with a soft iron jacket.

The transmitting and receiving coils were mounted on a wooden carrier with their axes vertical and 18 inches apart. Provision was made for limited adjustment of each coil. The requirement was that the electromagnetic centres of these coils should be at the same level. This was achieved by repeated traversing of the coils over a symmetrical model until adjustment of coil elevation gave the most symmetrical profile. Perfect symmetry of response was never achieved; the possible causes were that the transmitting and receiving coils were not of identical dimensions and that secondary pick-up in the feeding coil upset the constancy of the reference signal. The problem with the model equipment was that the coils were large with respect to the coil spacing when compared with the field equipment. Calibration of the equipment after the coils had been adjusted was carried out with all conducting material removed from the region of influence of the transmitting coil; this proved to be a zone within two coil separations from either coil.

Some difficulties were experienced with stray electromagnetic coupling in the model equipment not found with the field equipment. These were overcome by trial and error arrangements of the model equipment components.

A pair of rails carried the coil carrier; the models being investigated were clamped on to a wooden frame which permitted variation of their position to give the depth, dip, and strike required. The rails were graduated in intervals of 2¼ in (one eighth of the coil spacing) but readings were often taken at closer spacing on steep profile gradients.

The coil spacing used in the field was 200 ft and in the model tests 18 in. This gave a scale ratio of $1{:}133\frac{1}{3}$. Unfortunately it was not possible to reduce the model coils to the same ratio, and the coils were about 16 ft high in the scale of the rest of the model. This put the electromagnetic centre of the transmitting coil at 12 ft from its bottom end, which point was originally regarded as being at ground level. This error was found during the work measuring fields with a search coil (described later in this report), and is the cause of models being at some rather odd depths; 12 ft (0.06 of the coil spacing) has been added to the original depths of the models.

The choice of materials for the models was governed by the need for models which were easily handled and altered and by what was readily available. Steel grit was used for magnetic bodies; this is used in shot-blasting and was readily available and proved ideal for the purpose. Its overall conductivity was low owing to high intergrain contact resistance, and its bulk magnetic permeability was high.

Typical resistivities of materials used are:

copper	2	microhm-cm
aluminium	3	"
steel	15	"
lead	22	"

Keller & Frischknecht (1966, p. 296) and Ward (1967, p. 311) describe the criteria governing scaling factors. In our case for non-magnetic bodies the resistivity of the conductor in the field is $(133\frac{1}{3})^2$ or approximately 10 000 that of a conductor used in the model tests. For example a sheet of aluminium of three microhm-cm represents a conductor in the field of about 3×10^{-4} ohm-m, which is a very strong conductor.

3. THE DEPTH PROBE

It became apparent during the model tests with fixed coil spacing that a depth probing system using variable coil spacing could be developed by only minor modification of the equipment. The experiments which led to this idea were a series using a horizontal sheet to represent the top of a highly conductive massive body; these profiles are shown in Plate 5. It can be seen that well within the sheet the real component goes from less than 100% to over 100% and the imaginary component goes from negative to positive as the depth to the sheet increases; this was recognized as being a function of the geometry of a dipole magnetic field, and it was realized that a plot of the real component against coil spacing would give a curve with geometrical features dependent upon the depth of the structure being investigated. The development and field testing of the depth probe has been published (Duckworth, 1970) and is not described in this report.

4. SECONDARY FIELD MEASUREMENTS

If secondary field distributions could be measured they would provide direct evidence of centres of secondary current concentration and would be useful in understanding electromagnetic induction in complex structures. Some work was done with a search coil to try to determine the shape and magnitude of the secondary field around a conducting body. This required measurements of the direction and magnitude of first the primary field alone and then of a resultant field due to some model body; the secondary field was derived by vector subtraction. The measurements were done over an array of points in a vertical plane containing the traverse line and the transmitting coil axis.

A small search coil was constructed which was rotatable about an axis perpendicular to a vertical plane which contained the transmitting coil axis. The search coil was located by a matrix board suspended below the transmitting coil. By nulling the search coil signal by rotation, it was possible to plot the field direction at each point. When the field direction at a point is known the search coil can be set at 90° to this and the field strength measured. If field direction and strength measurements are made at a set of points first for the primary field alone and then for a resultant field, it should be possible by geometrical construction to derive the direction of the secondary field at those points and to obtain a measure of the strength of that field. Owing to the weakness of the secondary field this requires considerable accuracy in the measurement of field strength and direction, and the accuracy of the search coil used was not enough; the search coil was too large and amplification of its output was insufficient. A smaller coil and greater amplification would be an improvement (the Slingram amplifier was used to amplify the search coil signal); alternatively a Hall effect gaussmeter, which can use a very small sensing element, could be used.

The results of this work were not satisfactory and no results are shown in this report.

5. MAGNETIC EFFECTS

Many of the models used were steel sheets and boxes. This steel was less conductive than the aluminium used in other models and also had a magnetic effect. The difference in profiles using steel and aluminium sheets is illustrated in Plates 3 and 15 and by a comparison between Plates 1 and 4. The difference in profiles using steel and copper sheets is illustrated in Plates 4 and 10. The effect of the steel is to reduce the real component effects and to increase the imaginary component effects (this may be the effect of the decrease in conductivity) and to displace slightly the points where the real and imaginary components are 100% and zero (this is probably a magnetic effect). The magnetic effects of the steel sheets and boxes are small, and it is felt that the results using these steel models serve all the purposes required of them provided that the magnetic effects are borne in mind. Steel sheets have been used successfully by other workers (Ward, 1967, p. 315).

As a result of Bosschart's (1964) discussion of the influence of magnetic material on a Turam anomaly it was decided to investigate magnetic effects on Slingram anomalies. These magnetic effects have geological significance. For instance, rocks of the Golden Dyke Formation in the Rum Jungle area, N.T., contain zones of amphibolite which usually give rise to strong magnetic anomalies. Shale in the Golden Dyke Formation is highly conducting and models constructed of combinations of conducting and magnetic material simulate possible field conditions in the Rum Jungle area. Models consisting of magnetic material overlying conductors simulate possible field conditions of overlying magnetic laterite.

Magnetic effects were investigated using models made of steel grit. This had high bulk magnetic permeability and its overall conductivity was low due to high intergrain contact resistance. The magnetic effects are discussed with Plates 21 to 24. The magnetic models have small strike lengths; this is because it was found that the major magnetic effect comes from the material immediately below the coils and between them. Large masses of grit placed outside the coil system, either along the line of the coils or to the side, had no significant effect and anything below about one quarter of the coil spacing also had no significant effect unless it was close to a conducting body. Although the steel grit produced no imaginary component effects itself it strongly influenced the imaginary component effects of associated conductors as well as strongly influencing the real component effects.

6. DISCUSSION OF RESULTS

Results have been plotted midway between transmitter and receiver positions. The plates show distances in feet (x) and also as a function of coil spacing (r). The original results were plotted directly onto graph paper using a scale of 1 inch to 50 scale model feet. Thus using a scale in feet shows the results in the form in which they were recorded when the tests were being made. The results are also given as a function of coil spacing to facilitate comparison with results obtained with coil spacings other than 200 ft, for example coil spacings in metric units.

The plates show the dimensions of the models used and the positions of the models, but the models are not all drawn to scale. No strike directions are shown on the plates; all strikes are at 90^{o} to the traverses. In most of the plates the strike length can be considered infinite.

The causes for asymmetric profiles over symmetric models were discussed in Section 2 of this report.

Plate 1. These profiles show the effect of a thin highly conductive vertical aluminium sheet striking perpendicular to the traverse. The imaginary component response is much less than that of the real component. The flat-bottomed effect in both real and imaginary component anomalies for small depths can be shown by consideration of the field about a line current to be due to field geometry. The real component and, for the shallower depths, the imaginary component are 100% and 0% whenever either the transmitting or receiving coil is directly over the body. At the deeper depths the imaginary component is weak enough to be affected

by experimental error, and the 0% points do not coincide with those for the shallower depths.

Plate 2. The model used to produce these profiles was similar to that used to produce the profiles in Plate 1, but was thinner and had less depth extent. For small depths the real component anomaly is not as strong as in Plate 1, and the imaginary component anomaly is stronger. The reduction of the real component anomaly may be due to field distortion; that is, in Plate 1 the secondary field was circular, but in Plate 2 it is becoming one half of a horizontal dipole field, so that for the same depth the secondary field geometry is radically different. That is, the reduction of the real component anomaly may be due to the effect of the return current along the bottom edge of the sheet; the sheet acts as a single-turn coil with its axis horizontal, the position of the coil being closely related to the edges of the sheet. The effects of the lower return current oppose those of the upper return current, reducing the real component anomaly. However, the upper current is hardly detectable at depths greater than 100 ft, and the direct effect of the return current is difficult to credit. The increase in the imaginary component anomaly may be the result of a stronger self-induction effect owing to the currents in the upper and lower edges of the sheet being closer together.

Plate 3. These profiles show the effect of various dips on the response of a large sheet. The salient features are a broadening of the down-dip positive peak, displacement down-dip of the points where the real component is 100%, little displacement of the points where the imaginary component is zero, displacement of the real component minimum down-dip, and displacement of the imaginary component minimum up-dip. For small depths the up-dip real and imaginary component peaks are enhanced; for larger depths this is reversed. Small depths are not usually encountered in the field, and enhancement of the down-dip peaks is the feature likely to be observed in field results. The profiles over the steel sheet model were made for comparison and are essentially the same as over the aluminium sheet but with a reduced real component minimum and a stronger imaginary component minimum; this is due mainly to decrease in conductivity.

Plate 4. These profiles illustrate the effect of varying the model material. Materials used were copper, lead, and steel. Plate 1 shows profiles from the aluminium model. Approximate resistivities are copper 2 microhm-cm, aluminium 3, steel 15, and lead 22. The real component response increases and the imaginary component response decreases with decreasing resistivity; the ratios of the real component to imaginary component appear to increase with decreasing resistivity. The profiles over the steel model

include magnetic effects and are notable for the separation of the points at which the real and imaginary components are 100% and zero respectively. There appears to be a general elevation of the real component profile because the points at which the real component is 100% are less than half a coil spacing from the sheet.

Plate 5. These profiles illustrate the effect of a wide horizontal sheet at various depths. At small depths the profiles near the edge of the sheet are similar to that due to a line current; that is, an initial positive peak followed by a strong negative plunge. As expected, the profile is at a constant level well away from the edge of the sheet. The most significant feature of this set of profiles is that as the depth is increased, the real and imaginary components go from less than 100% and negative respectively to over 100% and positive well away from the sheet edge. This is significant in providing a method of depth determination. The irregularities in the real component profiles for small depths are probably due to the sheet not being perfectly flat.

Plate 6. These profiles show the effect which occurs when the coil system crosses a near-surface conductor which is approximately as wide as the coil spacing. The geological significance is that a wide body might tend to appear as two narrow parallel bodies. A physical explanation of the effect is that when the transmitting coil is over one edge of the sheet it induces a current to flow in the edges of the sheet. The current in the edge directly below the transmitting coil produces a field in opposition to the primary field; the return current along the edge near the receiving coil does not oppose the primary field, and it is the field due to the return current which most strongly affects the receiver.

Plate 7. These profiles are from a steel box of finite depth extent and strike, and are similar to the profiles in Plates 1, 2, and 4. The magnetic effects are probably the cause of the displacement of the 100% and 0% crossing points, as was the case in Plate 4.

Plate 8. These profiles show the response from the steel box of Plate 7 at various dips and depths. The real component of Profile 1 has a minor negative dip around x = 200 ft. This is probably the effect of the bottom edge of the box being within range of detection (that is, less than 100 ft). The imaginary component minimum at x = 100 ft may also be the effect of the bottom edge of the box.

Plate 9. The profiles over the horizontal steel box again show the effect of a near-surface horizontal conductor of width approximately that of the coil spacing, and can be

compared with the profiles in Plate 6. The profiles can also be compared with those in Plates 7 and 8 in which the steel box is vertical and at various dips. The profiles over the two vertical steel boxes provide direct comparison with the horizontal box profiles. It is probable that in field results, the effects of two vertical conductors could be difficult to distinguish from a horizontal conductor. When comparing the profiles in this plate, it should be remembered that the strong positive peak in the middle of the horizontal box would be attenuated as the depth increases.

Plate 10. These profiles show the response of a vertical steel body 50 ft wide at various depths; magnetic effects are apparent (see Plate 4). This plate also shows the profiles over a similar body of copper. As expected there is a noticeably weaker imaginary component response with the more conductive copper.

Plates 11 to 14. These profiles are from bodies of various widths at various depths. Steel was the material used throughout. The main point of interest is the positive real component response over wide bodies at large depths. This is consistent with the results in Plate 5. The strong positive real component response at the centre of the strong negative response shown by the 150 ft and 200 ft wide bodies at small depths is consistent with the effects shown in Plates 6 and 9.

Plate 15. These profiles are similar to those in Plate 5; the addition of the vertical sheet mainly alters the profiles away from the horizontal sheet. The profiles over the aluminium sheet show that the magnetic effect of the steel sheets is small; the differences between Profiles 1 and 2 are due mainly to the difference in conductivity of the materials.

Plate 16. These models were used to see if the edge of a wide conducting body could be recognized to be dipping from the characteristics of the Slingram profiles. Comparison of these profiles with those for a body with a vertical side in Plate 15 shows only minor differences which would probably be unrecognizable in field results.

Plate 17. These profiles show the merging of anomalies. In the case of the two horizontal bodies (top profiles) the resultant profiles could probably be interpreted to be due to three separate, thin tabular vertical bodies. A similar effect is shown in Plate 9. The bottom profiles indicate the three separate bodies; the bodies are far enough apart to produce individual anomalies.

Plate 18. The masking of the response of one model by another is shown here; the composite profile for the box and sheet is virtually indistinguishable from that on earlier plates of the sheet alone. Plates 15 and 16 show similar effects. The second model shown consists of two horizontal steel sheets with a gap between them representing 20 ft. The model probably has little practical value, but is interesting for the way in which the responses of the edges of each sheet are merged.

Plate 19. As it appears that currents concentrate in the edges of a body, it was conjectured that a sheet of metal might be replaced by a wire frame. An aluminium box was made and then a wire frame of the same dimensions. The same magnitude of response was not expected, but the same shape was. However, the shape of the profile due to the wire frame is different from that due to the box.

The second profile shows the effect of dissemination. The first model was a flat sheet of aluminium foil which was traversed first as a whole sheet, and again when it had been cut into one inch squares, retaining the same shape and area as the original sheet. Care was taken to ensure that each one-inch square was isolated from its neighbours. The response of the disseminated body is negligible. The third model was a cardboard box; it was wrapped in aluminium foil to represent a massive highly conductive body, and was packed with small pieces of foil to represent a highly conductive disseminated body of the same shape and size. Again the response of the disseminated body was negligible.

Plate 20. This and the following plates illustrate the influence of highly magnetic material. The model here was a plastic tray full of steel grit. The profiles show a strong positive real component anomaly; the imaginary component is not shown because it was zero at all points for all depths of the model. Theory predicts a positive real component anomaly for a highly magnetic model. This plate also shows an attempt to provide a wide magnetic model. It is evident that had the box been longer a constant positive real component level would have been reached over the centre of the body. The imaginary component effects are due to small steel strips in the box containing the steel grit.

Plate 21. This shows the results of an attempt to see if a magnetic effect could influence the response of a strong conductor; a traverse was run over a hollow steel box when empty, and when filled with steel grit. The response (Profile 2, top set) was identical in each case. A wooden box of the same dimensions as the steel box was filled with steel grit and put in place of the steel box; the real component response (Profile 1) was quite strong and the imaginary component was zero. This it seems that in a

strong conductor the skin effect would be predominant and the primary field would be so attenuated at the surface of the body that it would not be influenced by internal bulk magnetic effects. The Plate also shows the effect of a magnetic body on a horizontal sheet. The profiles shown are from a horizontal aluminium sheet alone, the sheet covered by a layer of grit, and the layer of grit alone. The imaginary component for the grit alone was expected to be zero, but the box holding the grit had some small steel strips in it. The profiles show that with what might be considered as a magnetic overburden, the negative real component response was strongly attenuated and the imaginary component response remained largely unaffected.

Plate 22. By putting the steel grit in bags and later in small cylindrical plastic boxes, a greater variety of magnetic models became possible. In this case a wall of magnetic material was built on either side of a thin vertical sheet conductor. The magnetic wall has strongly enhanced the positive real component features and diminished the central negative feature. In addition, there is some enhancement of both the positive and negative parts of the imaginary component. The irregularities in the profiles over the magnetic body are due to the wall not being homogeneous; it was built of ill-fitting bags of grit. The second model shown on this Plate is similar to the first but the magnetic body is longer. The real component is now everywhere positive and the imaginary component effect is far stronger than would be expected from the sheet alone. It appears that although the magnetic material produces no imaginary component effects itself, it is capable of strongly influencing the imaginary component effects of associated conductors. The irregularities are due to the magnetic model being built of boxes of grit which did not fit together well.

Plate 23. These models are much the same as in Plate 22. The first has an aluminium instead of the steel sheet of Plate 22. The aluminium sheet on its own has a weaker imaginary response than the steel sheet, but it is still enhanced by the magnetic body; the real component response is enhanced positively, especially where the original response due to the sheet was positive. The second model is similar to the first but with a steel sheet and with the sheet deeper. The real component profile is now almost totally positive. Plate 23 can be compared with Plate 1 to see how profoundly the magnetic material modifies the effect of the conductor. Again, the irregularities are due to the magnetic model being built of boxes of grit which did not fit together well.

Plate 24. The first model can be considered analogous to magnetic overburden covering a contact between a highly conducting and a poorly conducting rock. As expected from

previous Plates the effect is to generally elevate the real component due to the sheet alone. The second model shows how completely magnetic influences can alter the response of a conductor, for in this case the real and imaginary component profiles are completely separated. Once more the irregularities in the profiles are due to the inhomogeneous construction of the magnetic body.

7. CONCLUSIONS AND RECOMMENDATIONS

The model tests have proved useful in revealing the profiles to be expected over various structures. Perhaps the most interesting revelations have been the magnetic effects and the inter-relationship between the geometries of a structure under investigation and the coil system in use.

Further development of the equipment could include construction of a coil system with smaller coils more nearly in scale, and construction of a multifrequency system so that probing by frequency variation can be investigated. Possibly the transmission frequency of the model equipment could be scaled up so that ionic conductors could be used, but this would probably be difficult.

The use of the search coil system for investigating field shapes and magnitudes needs developing.

Fixed coil spacing work could be done on (1) the effect on response when the traverse is not perpendicular to the strike of the body, (2) the effect of prominences on wide conducting bodies, (3) more investigations of the masking of one conductor by another, (4) more tests of non-conducting magnetic bodies including variations of magnetic permeability, and (5) more tests of the effect of magnetic bodies on the response of conducting bodies.

Model materials need development, particularly to provide a bulk conducting material with controllable resistivity and magnetic permeability. This may be achieved by using wax mixed with a conductive paint, and steel grit. If a bulk model material is developed some means will be required for measuring resistivity and magnetic permeability in samples of it.

Further probe work could be done, for instance on dipping structures not parallel to the strike and on bodies at various dips and depths. The effect of variation of magnetic permeability on the relation between depth and coil spacing could be investigated; anisotropic bodies could be constructed and investigated with probes at right angles to one another.

The work up to this stage has proved valuable in illustrating qualitative features; in addition the depth probe, a direct outcome of the tests, permitted some quantitative depth information to be derived.

8. REFERENCES

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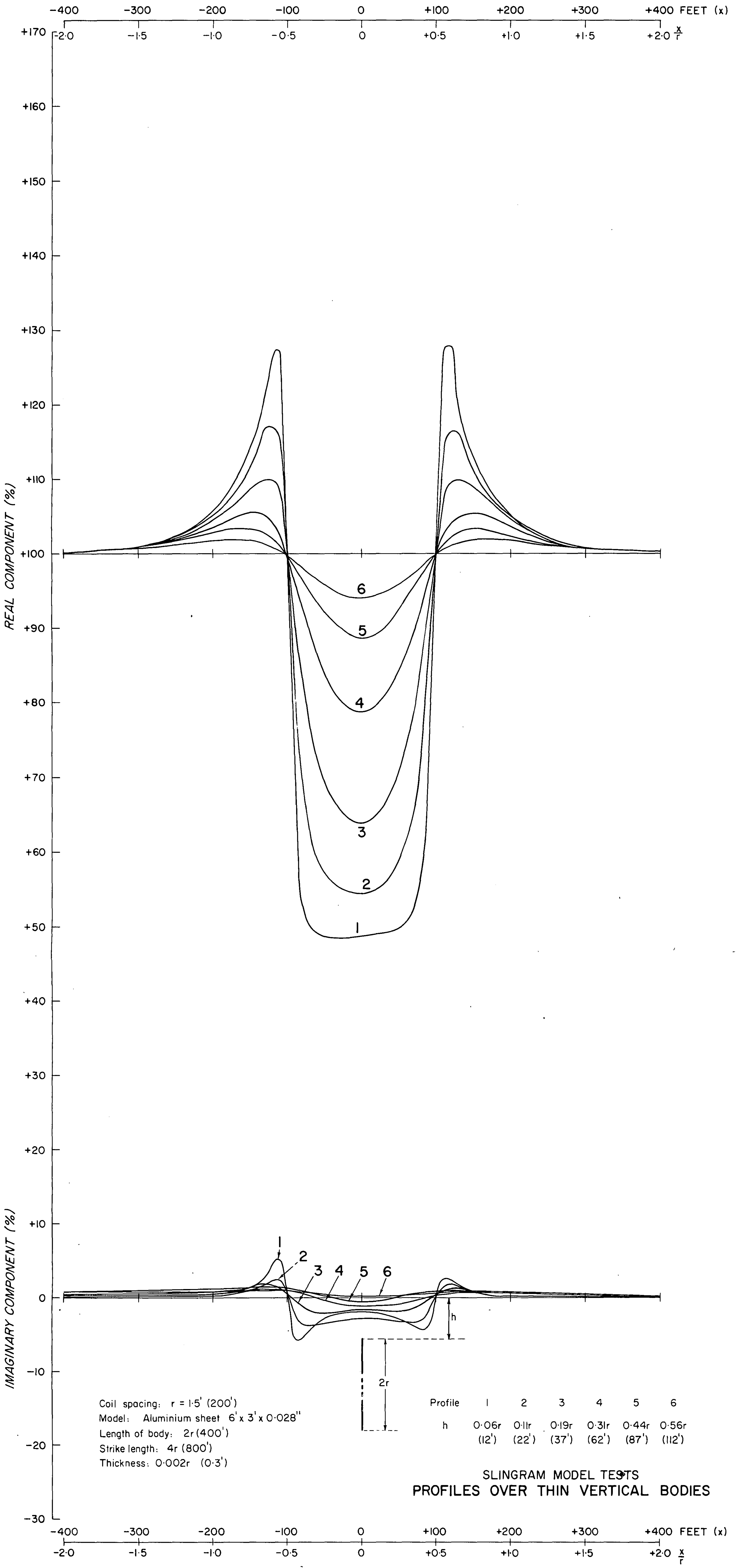
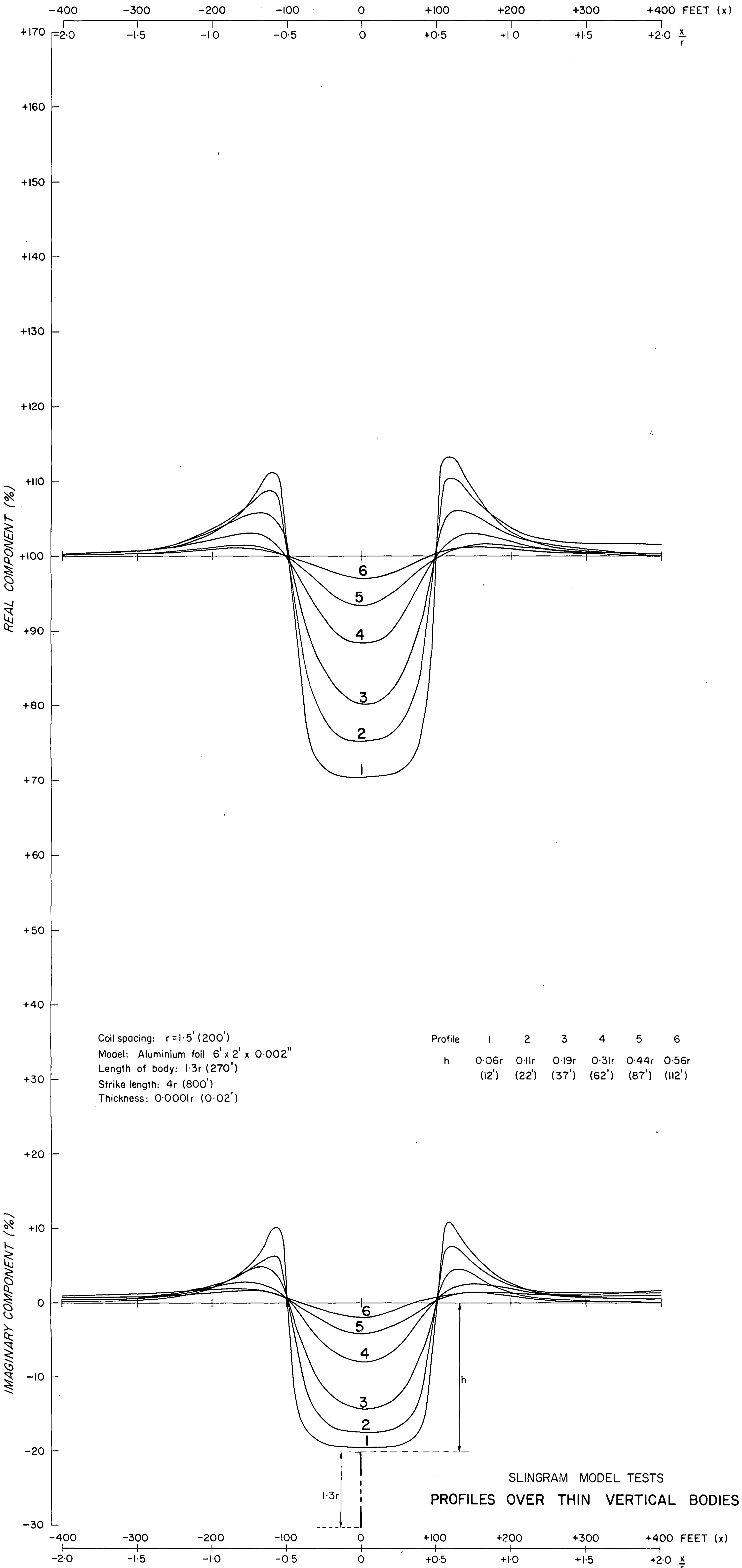


SLINGRAM MODEL TESTS
PROFILES OVER THIN VERTICAL BODIES

PLATE 1

To accompany Record No. 1974/63

G29-175



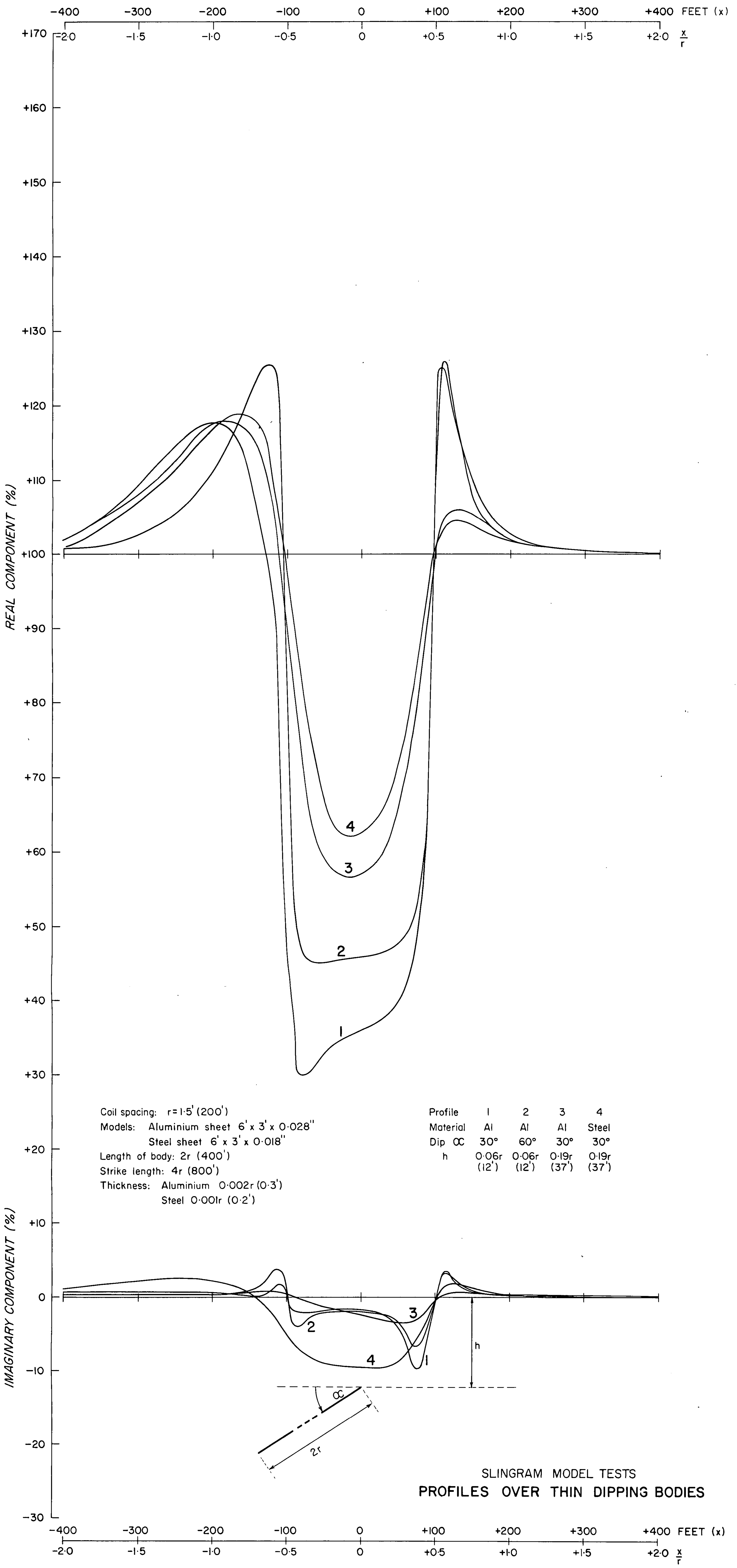
SLINGRAM MODEL TESTS

PROFILES OVER THIN VERTICAL BODIES

PLATE 2

To accompany Record No. 1974/63

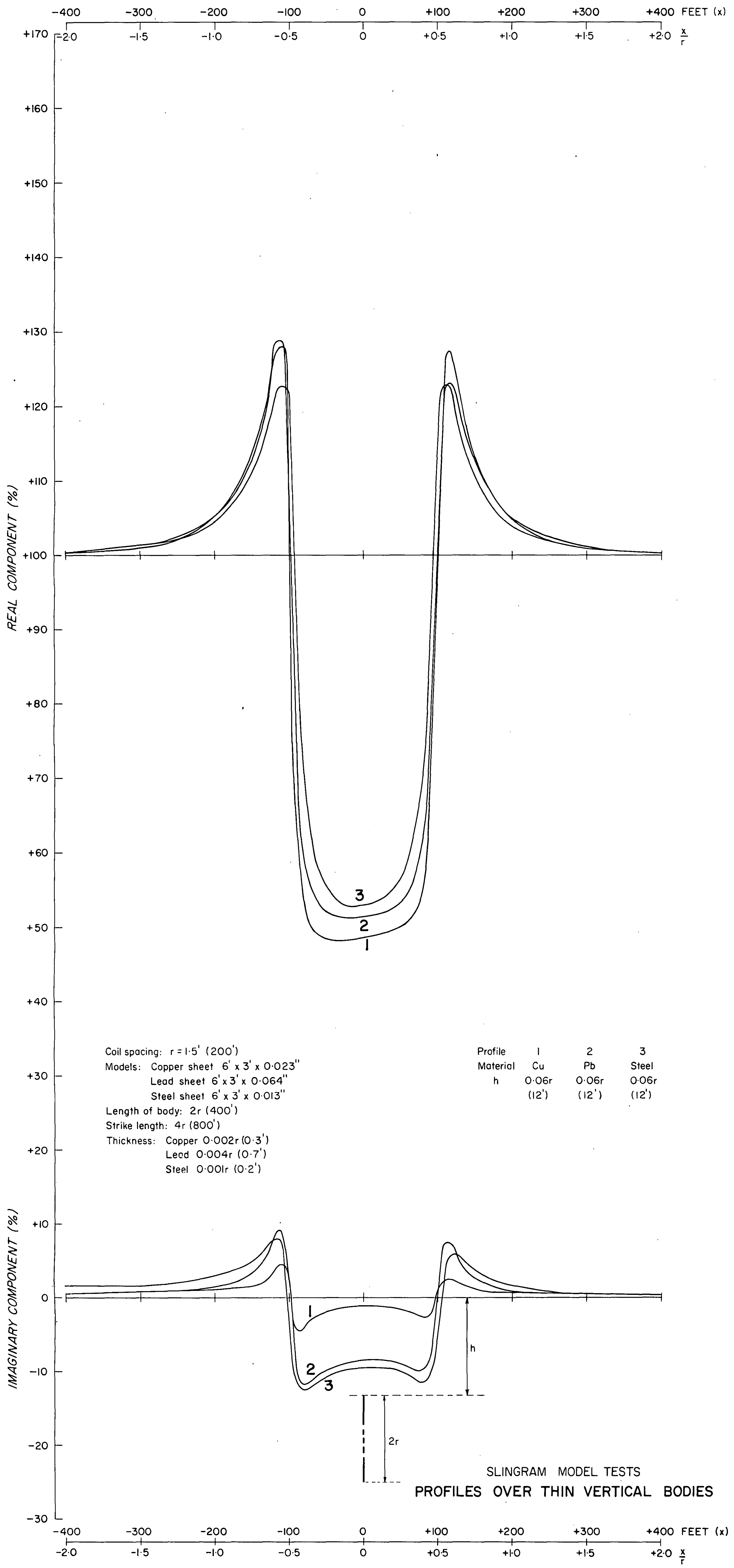
G29-176



SLINGRAM MODEL TESTS

PROFILES OVER THIN DIPPING BODIES

PLATE 3



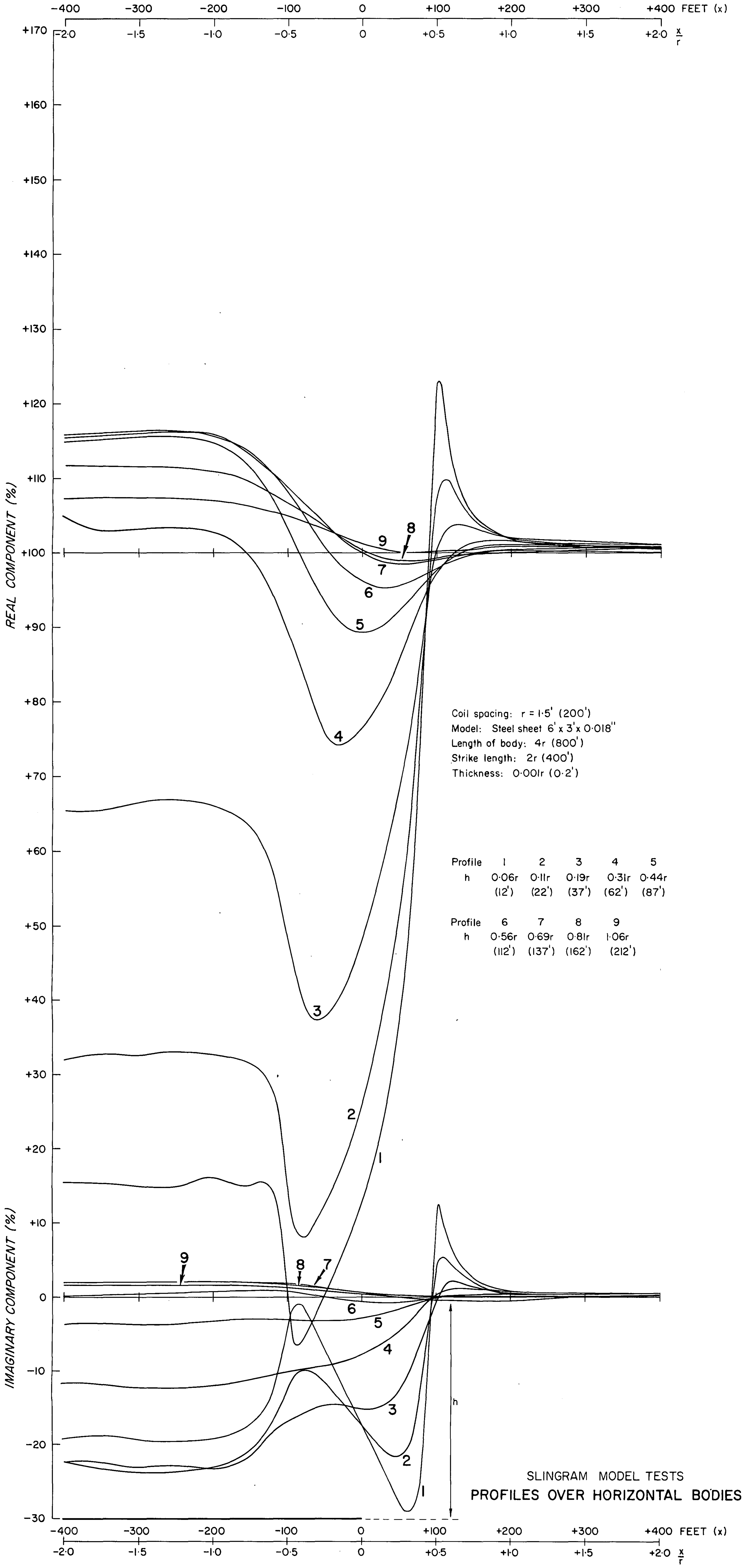
SLINGRAM MODEL TESTS

PROFILES OVER THIN VERTICAL BODIES

PLATE 4

To accompany Record No.1974/63

G29–178



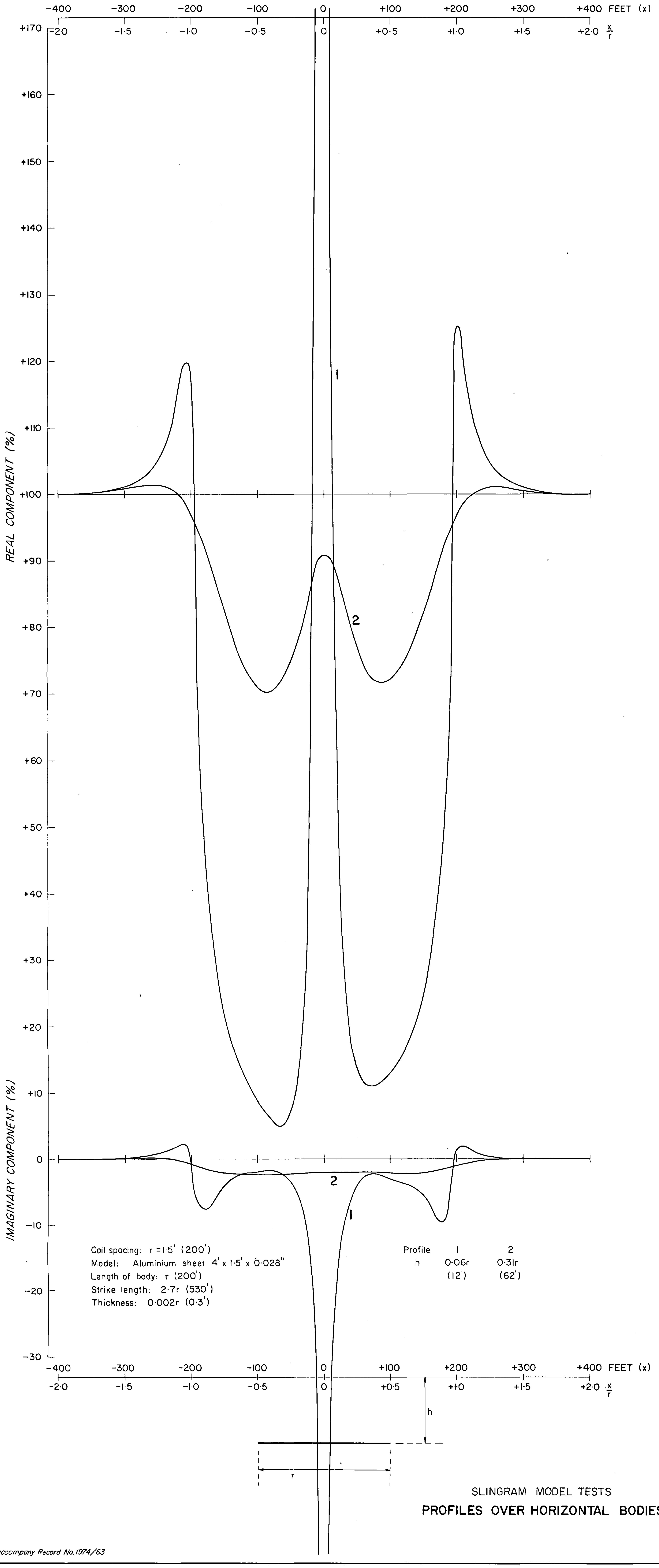
SLINGRAM MODEL TESTS

PROFILES OVER HORIZONTAL BODIES

PLATE 5

To accompany Record No. 1974/63

G29-179



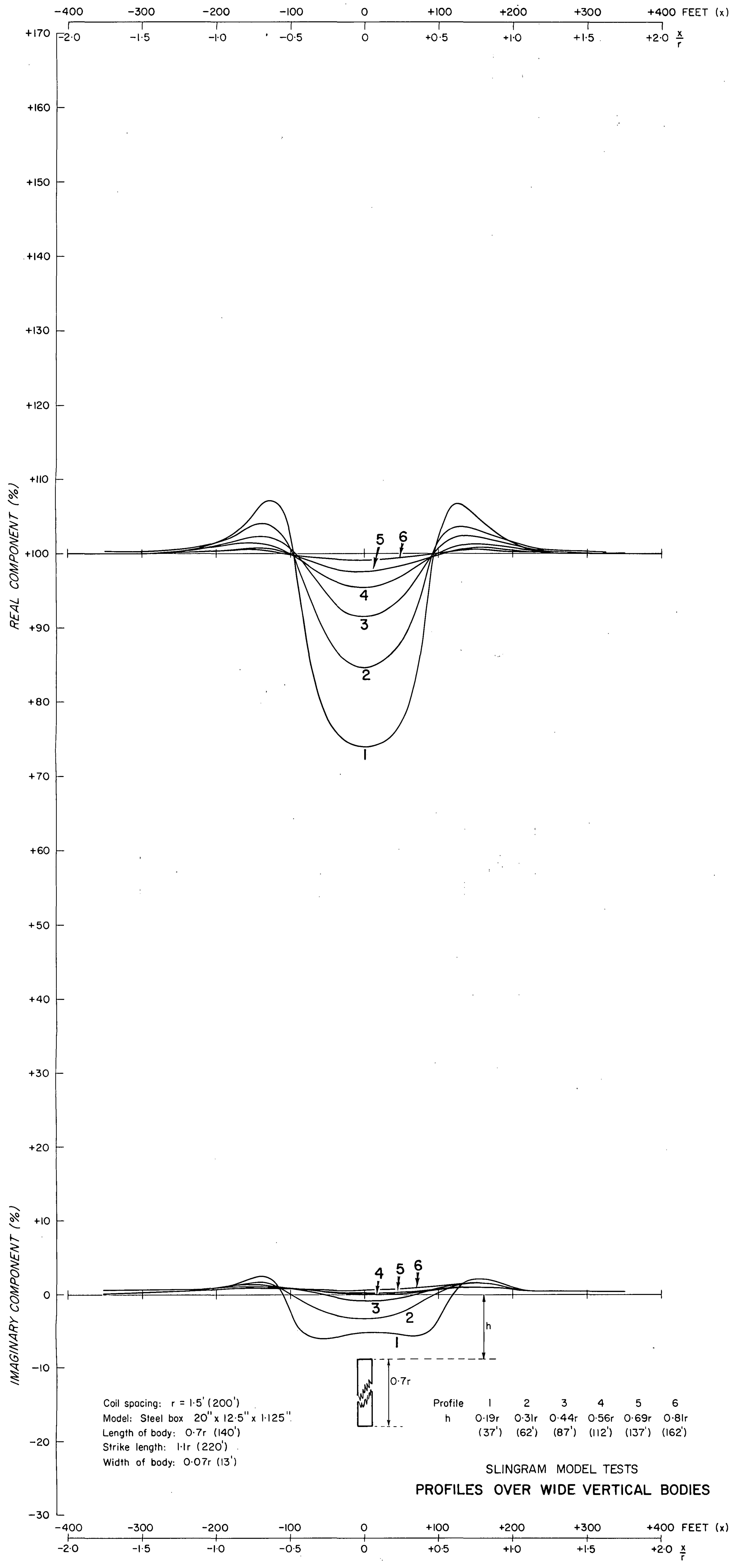
SLINGRAM MODEL TESTS

PROFILES OVER HORIZONTAL BODIES

PLATE 6

To accompany Record No. 1974/63

G29-180



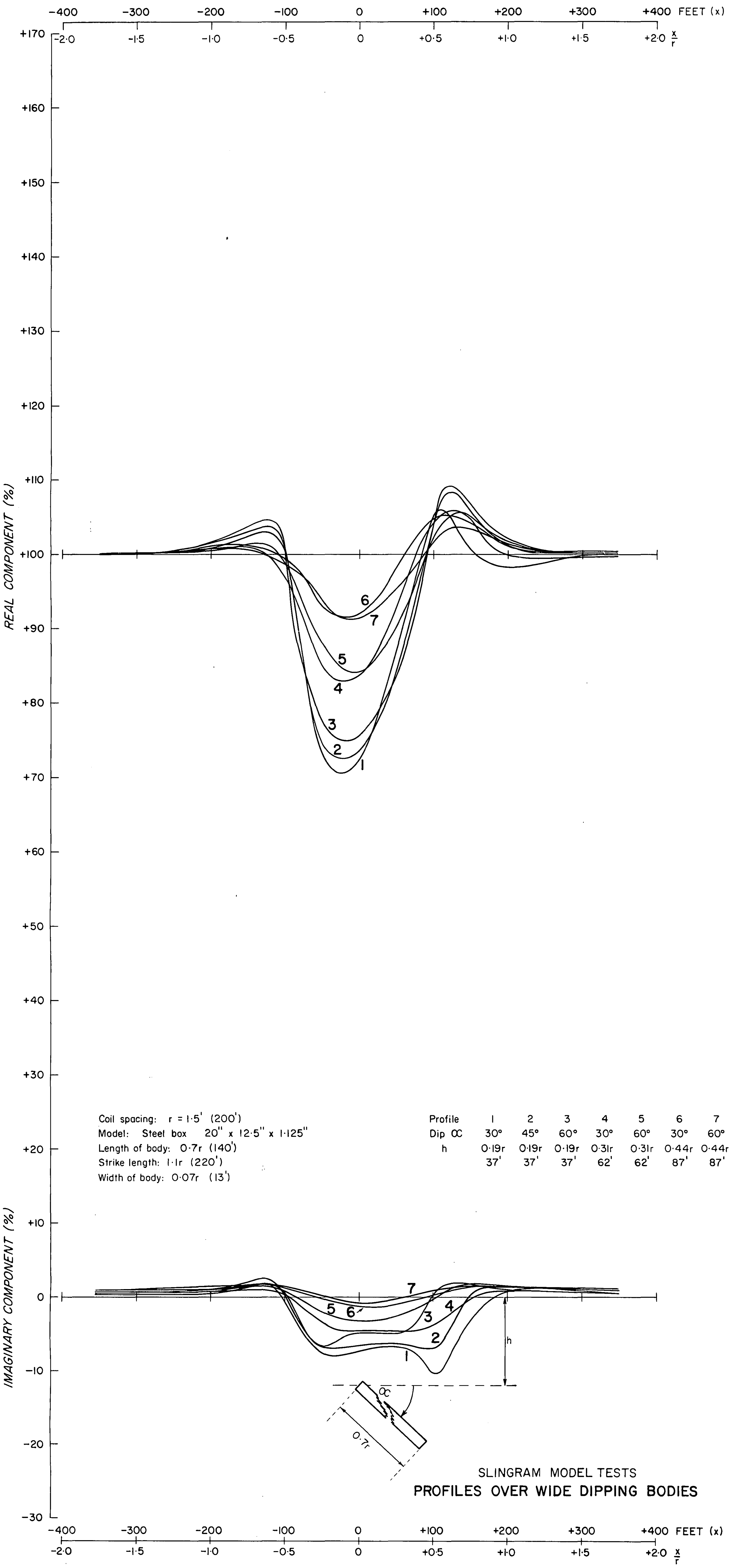
SLINGRAM MODEL TESTS

PROFILES OVER WIDE VERTICAL BODIES

PLATE 7

To accompany Record No. 1974/63

G29-181



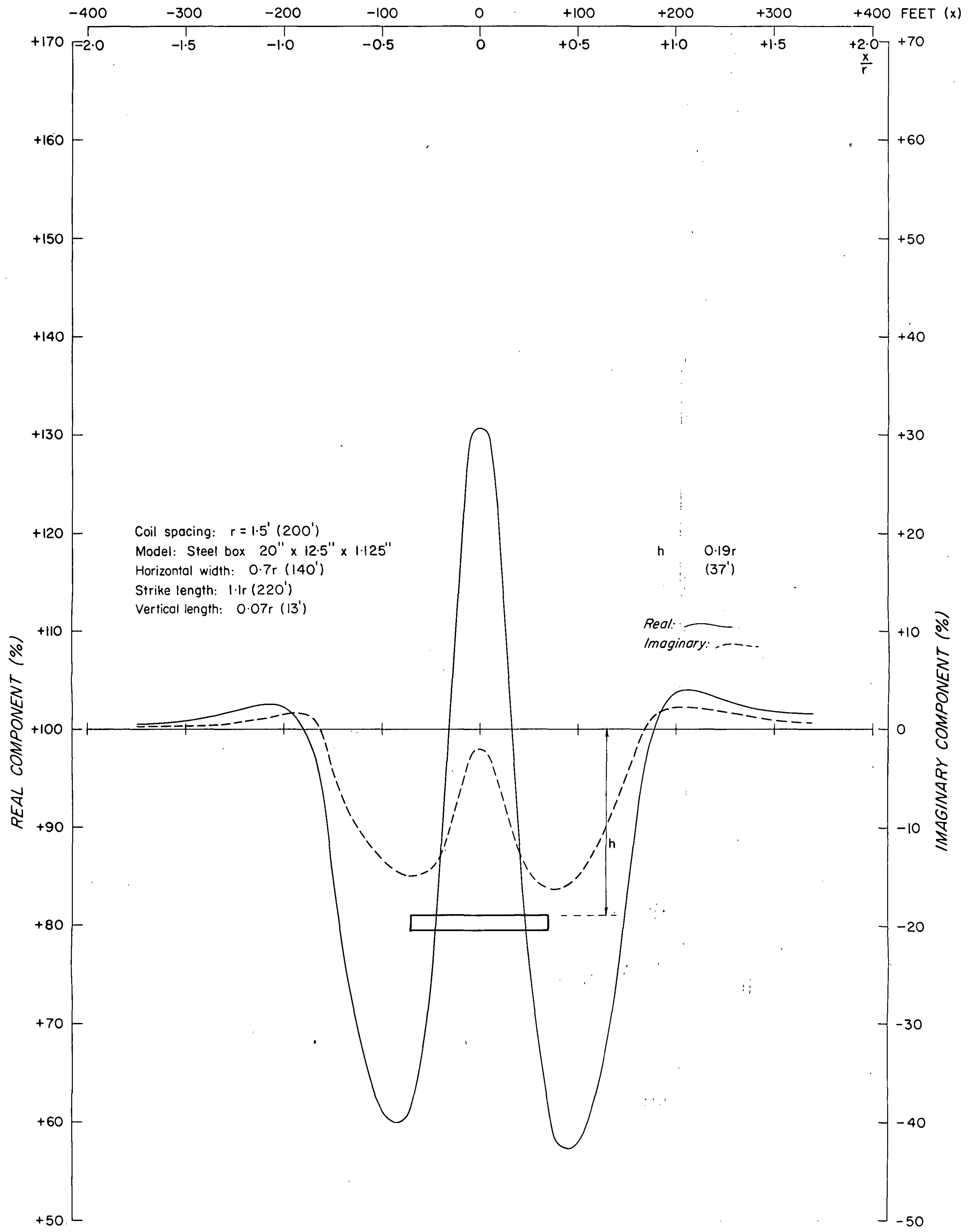
SLINGRAM MODEL TESTS

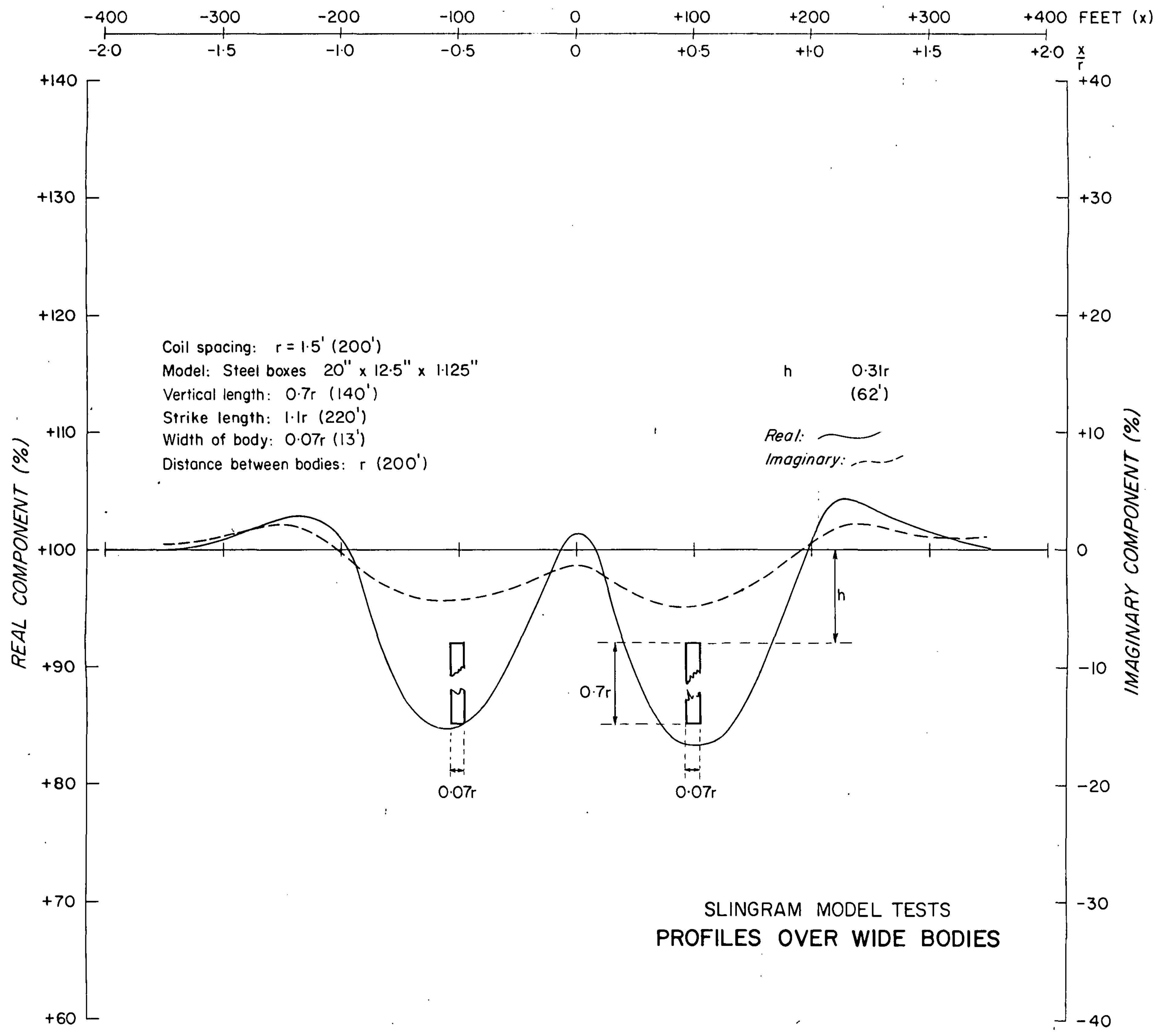
PROFILES OVER WIDE DIPPING BODIES

PLATE 8

To accompany Record No.1974/63

G29-182





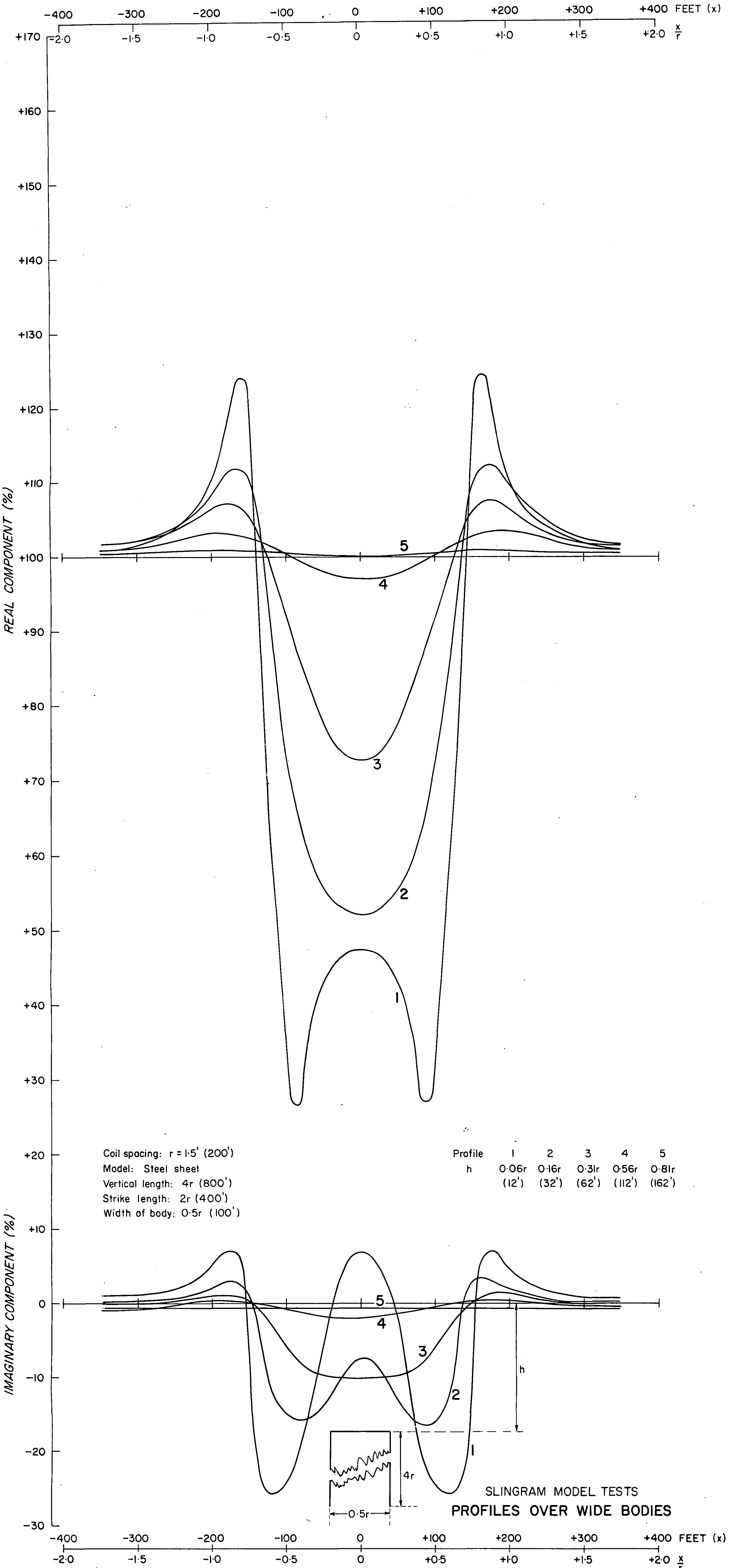
SLINGRAM MODEL TESTS

PROFILES OVER WIDE BODIES

PLATE 9

SLINGRAM MODEL TESTS
PROFILES OVER WIDE BODIES

PLATE 10



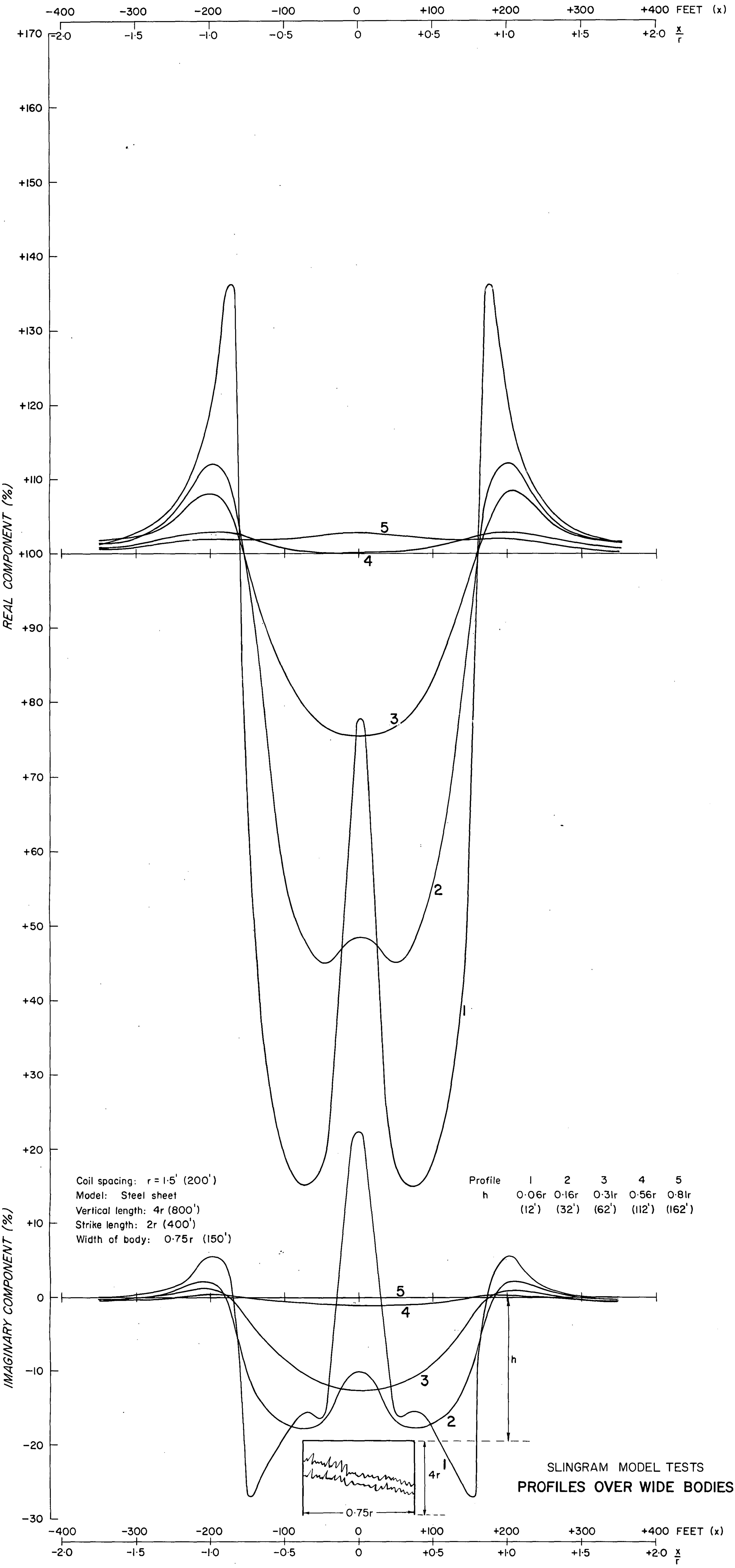
SLINGRAM MODEL TESTS

PROFILES OVER WIDE BODIES

PLATE 11

To accompany Record No. 1974/63

G29-185



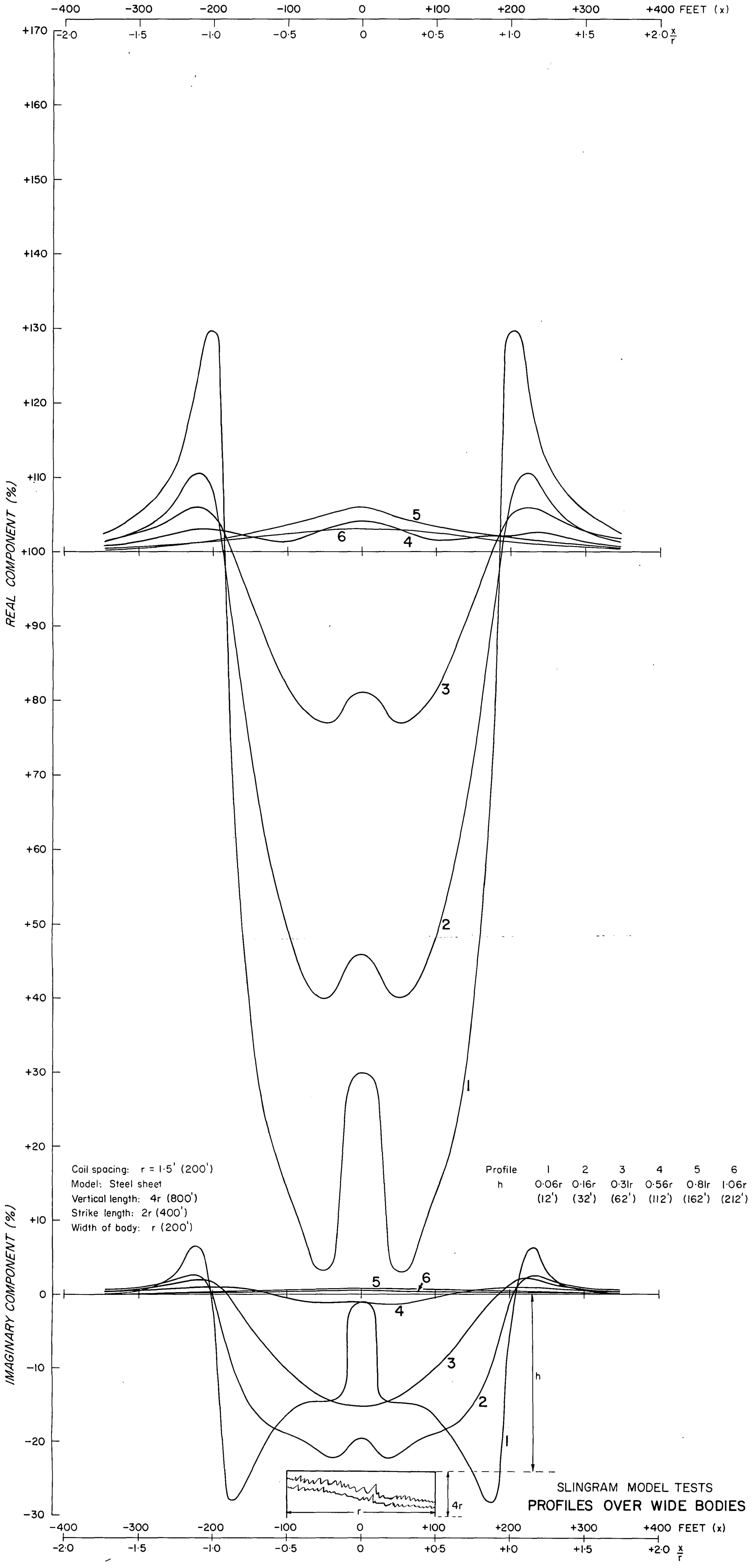
SLINGRAM MODEL TESTS

PROFILES OVER WIDE BODIES

PLATE 12

To accompany Record No.1974/63

G29-186

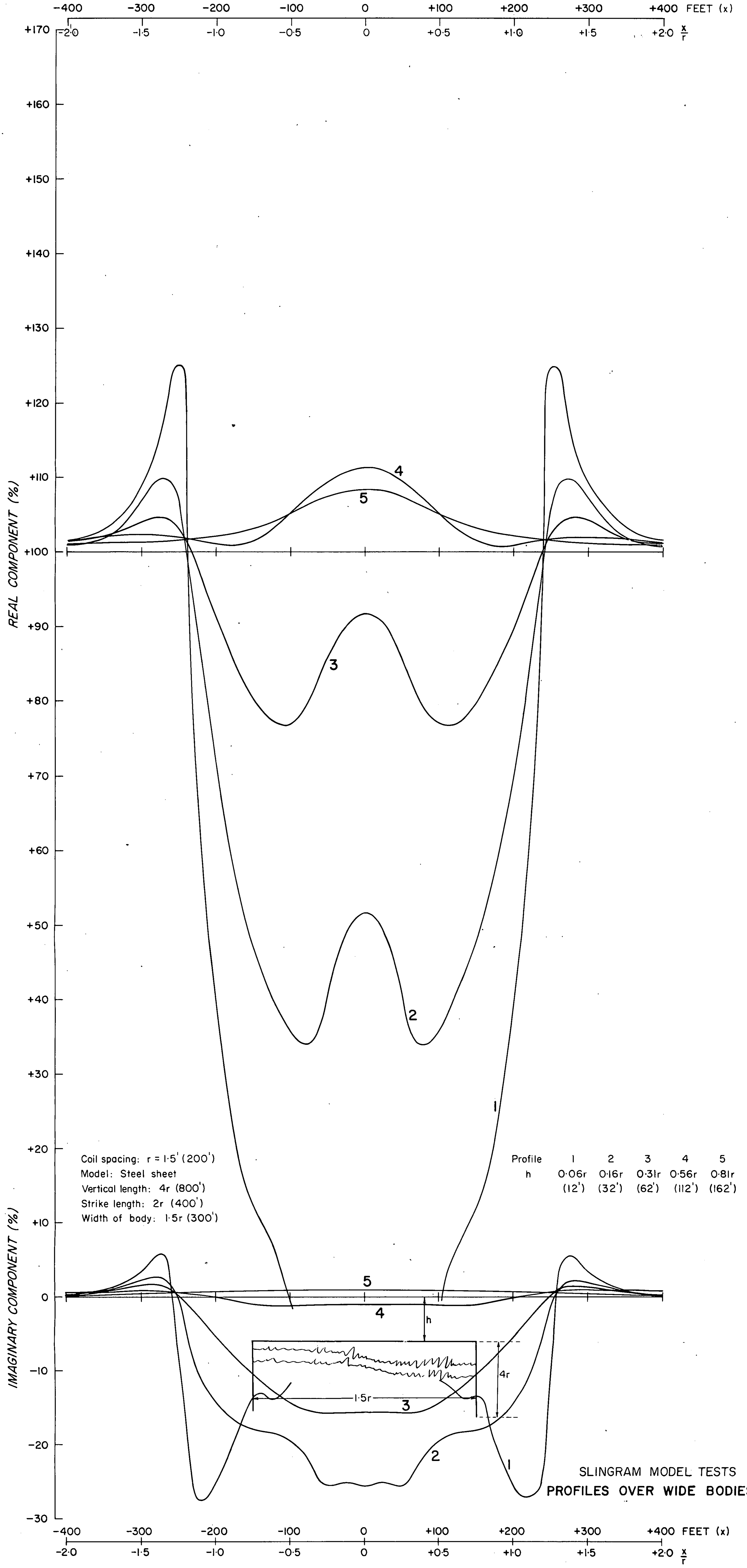


SLINGRAM MODEL TESTS
PROFILES OVER WIDE BODIES

PLATE 13

To accompany Record No.1974/63

G29-187



SLINGRAM MODEL TESTS

PROFILES OVER WIDE BODIES

PLATE 14

To accompany Record No. 1974/63

G29-188

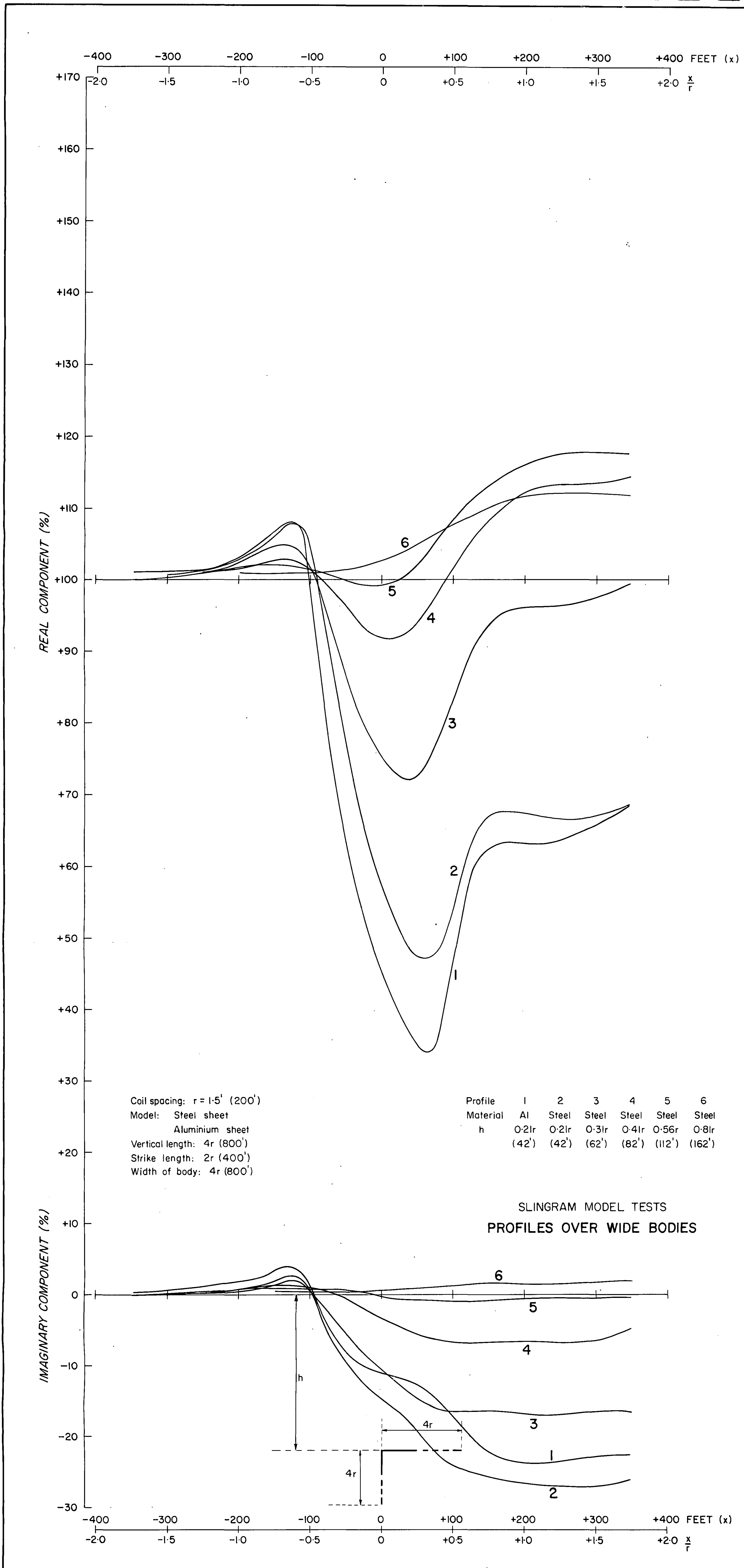
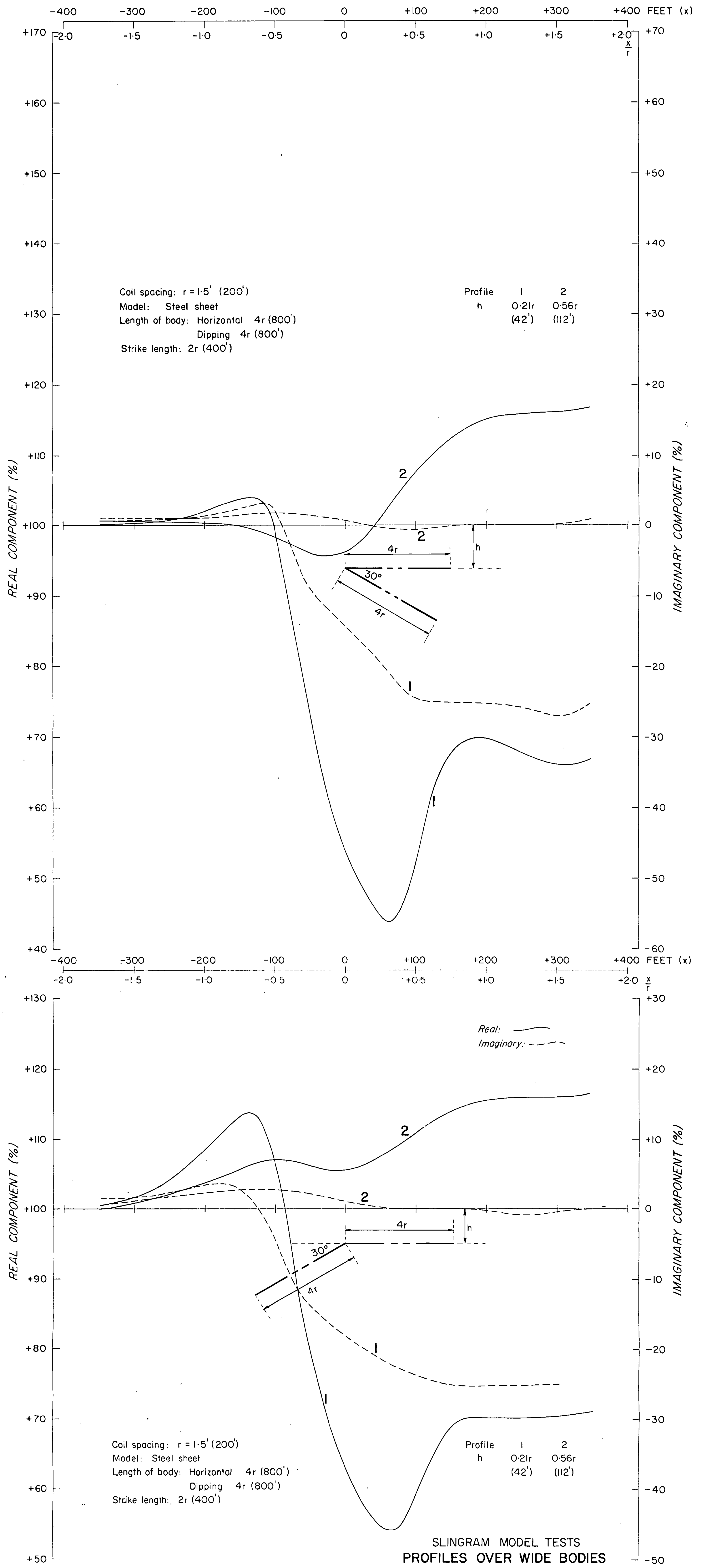


PLATE 15

To accompany Record No. 1974/63

G29-189

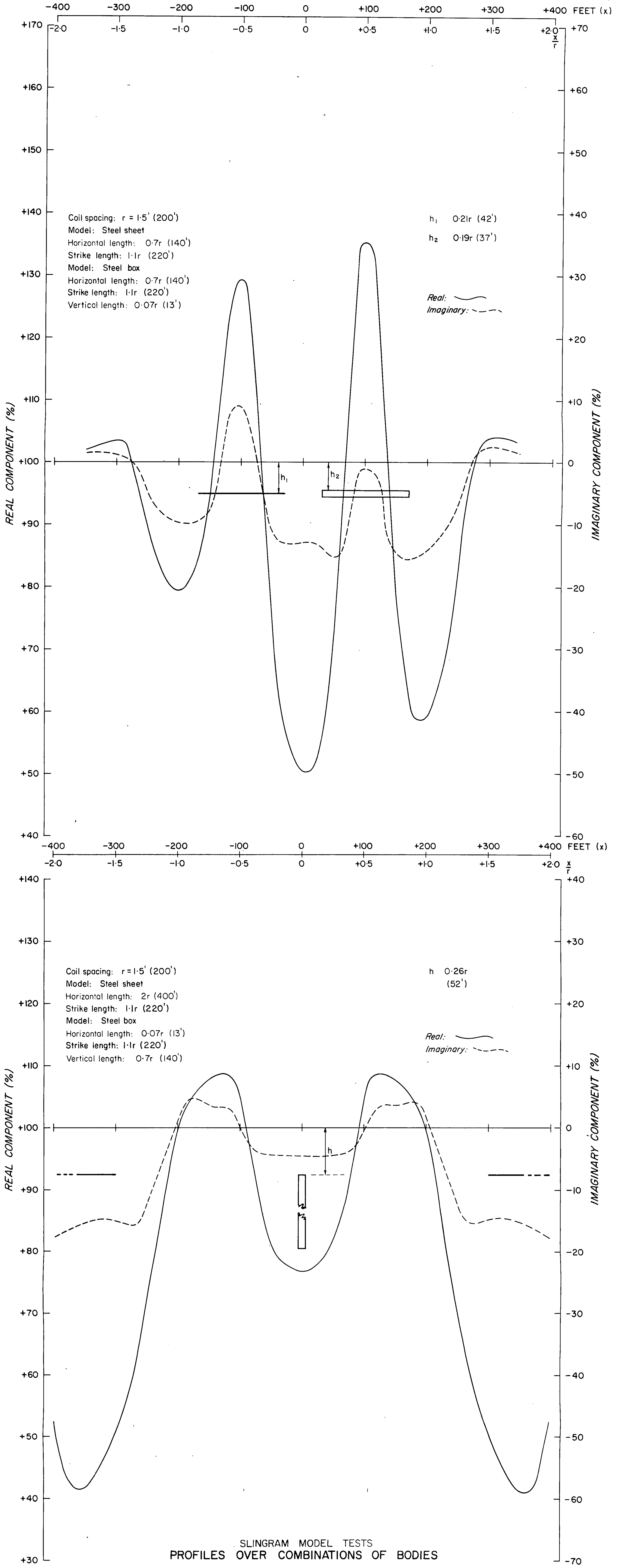


SLINGRAM MODEL TESTS
PROFILES OVER WIDE BODIES

PLATE 16

To accompany Record No. 1974/63

G29-190



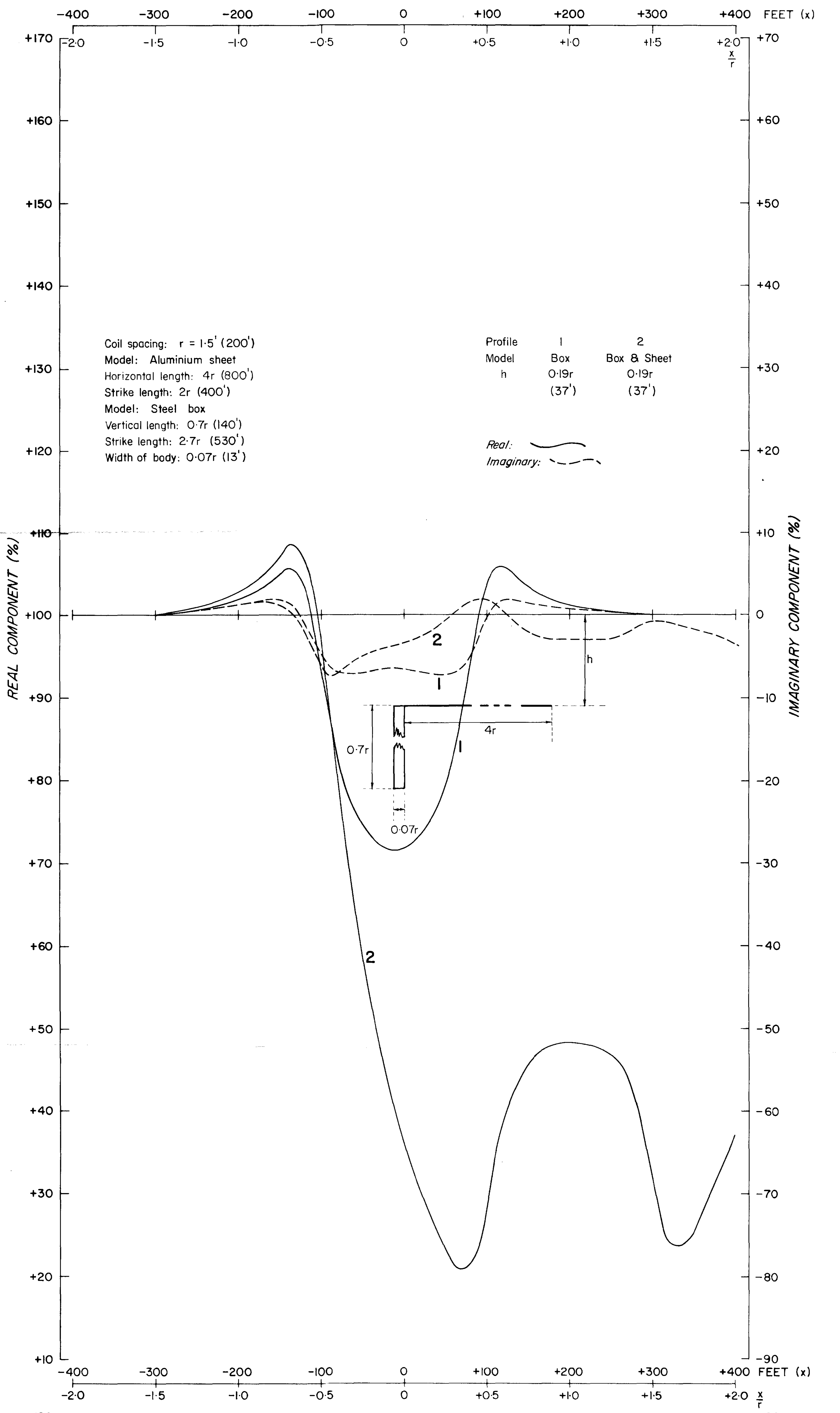
SLINGRAM MODEL TESTS

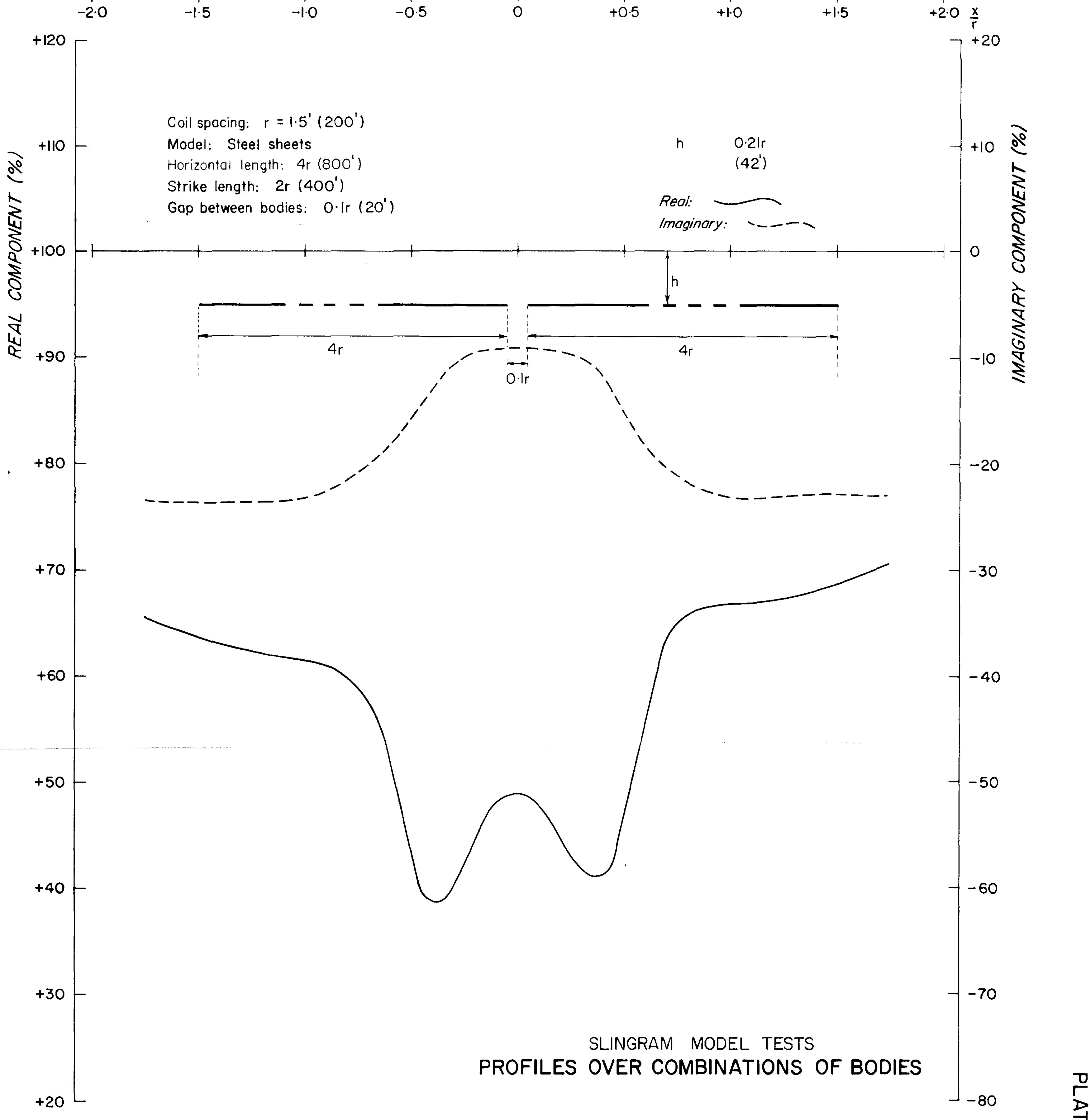
PROFILES OVER COMBINATIONS OF BODIES

PLATE 17

To accompany Record No.1974/63

G29-191





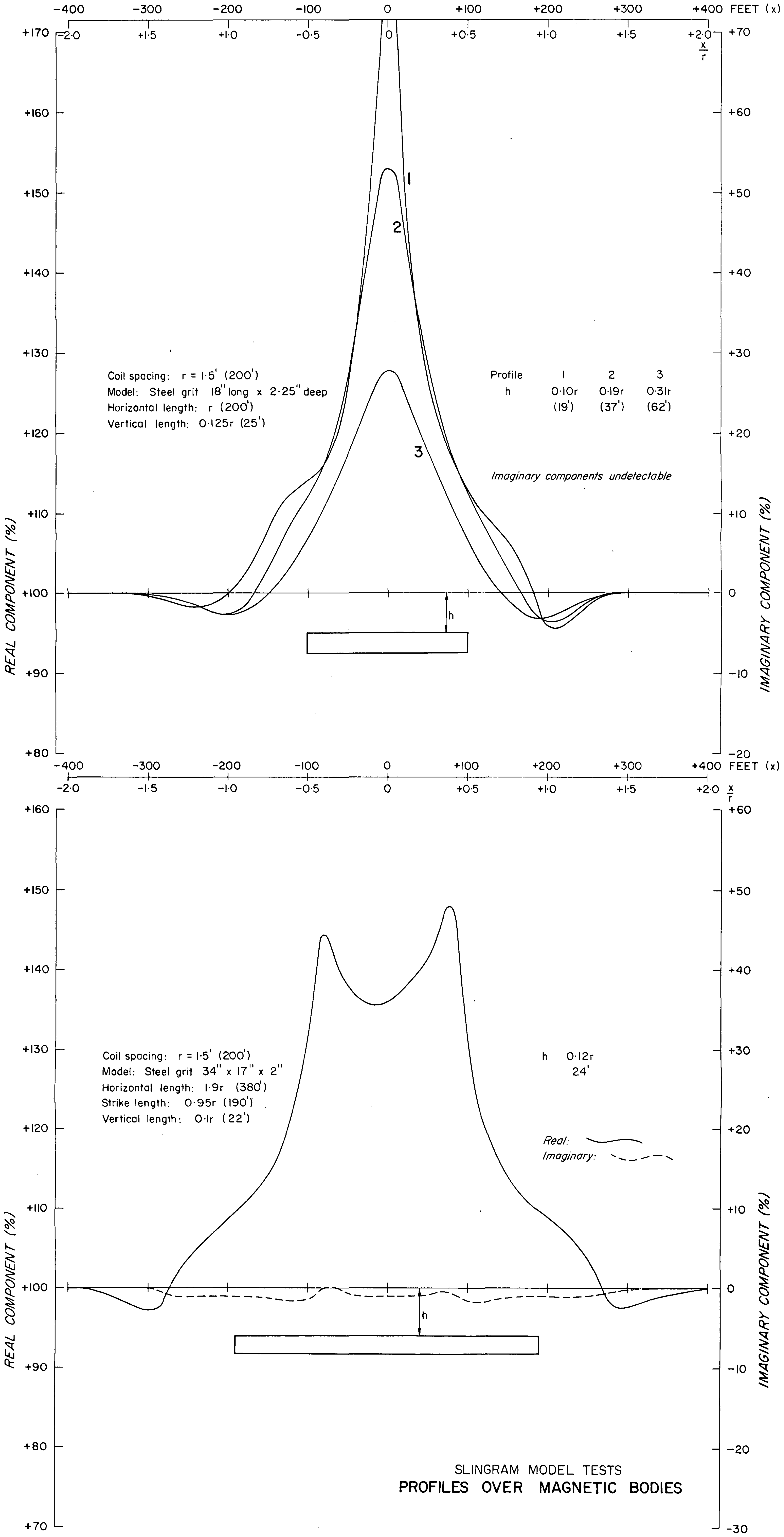
SLINGRAM MODEL TESTS

PROFILES OVER COMBINATIONS OF BODIES

PLATE 18

SLINGRAM MODEL TESTS
PROFILES OVER COMPOSITE BODIES

PLATE 19



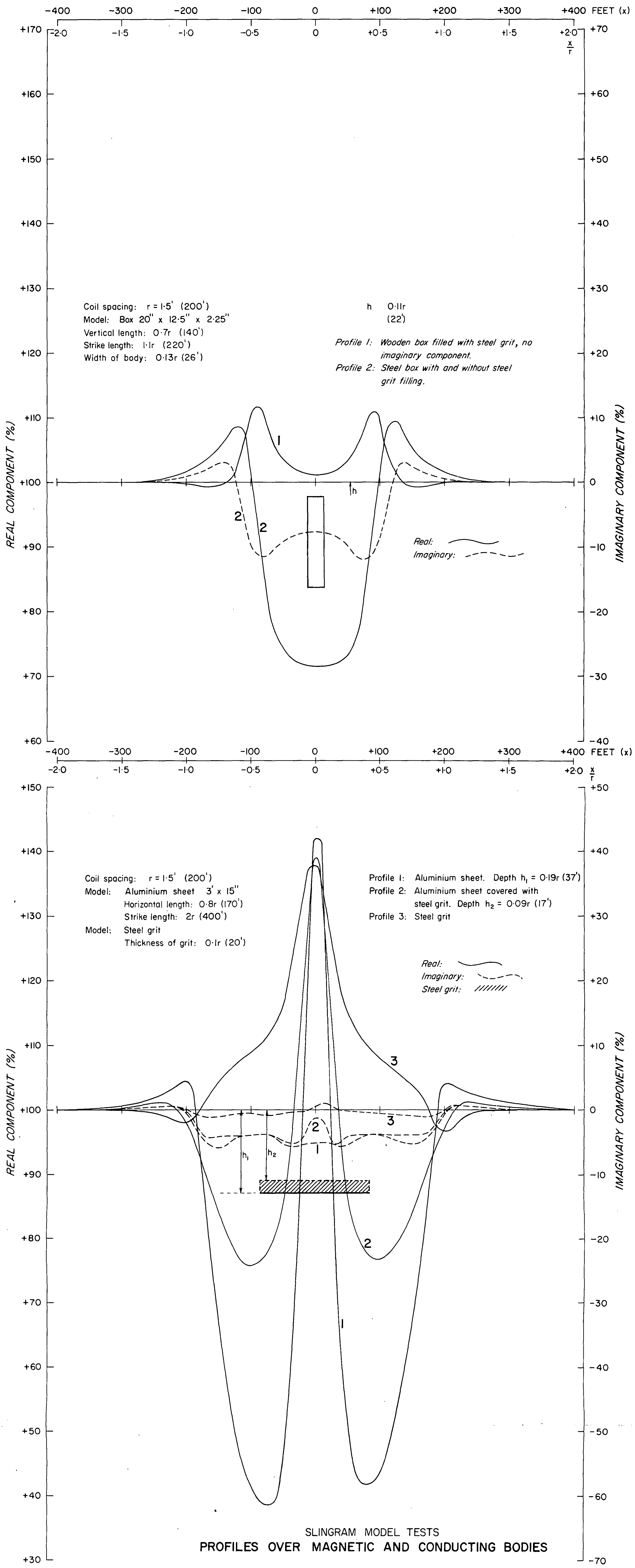
SLINGRAM MODEL TESTS

PROFILES OVER MAGNETIC BODIES

PLATE 20

To accompany Record No. 1974/63

G29-194



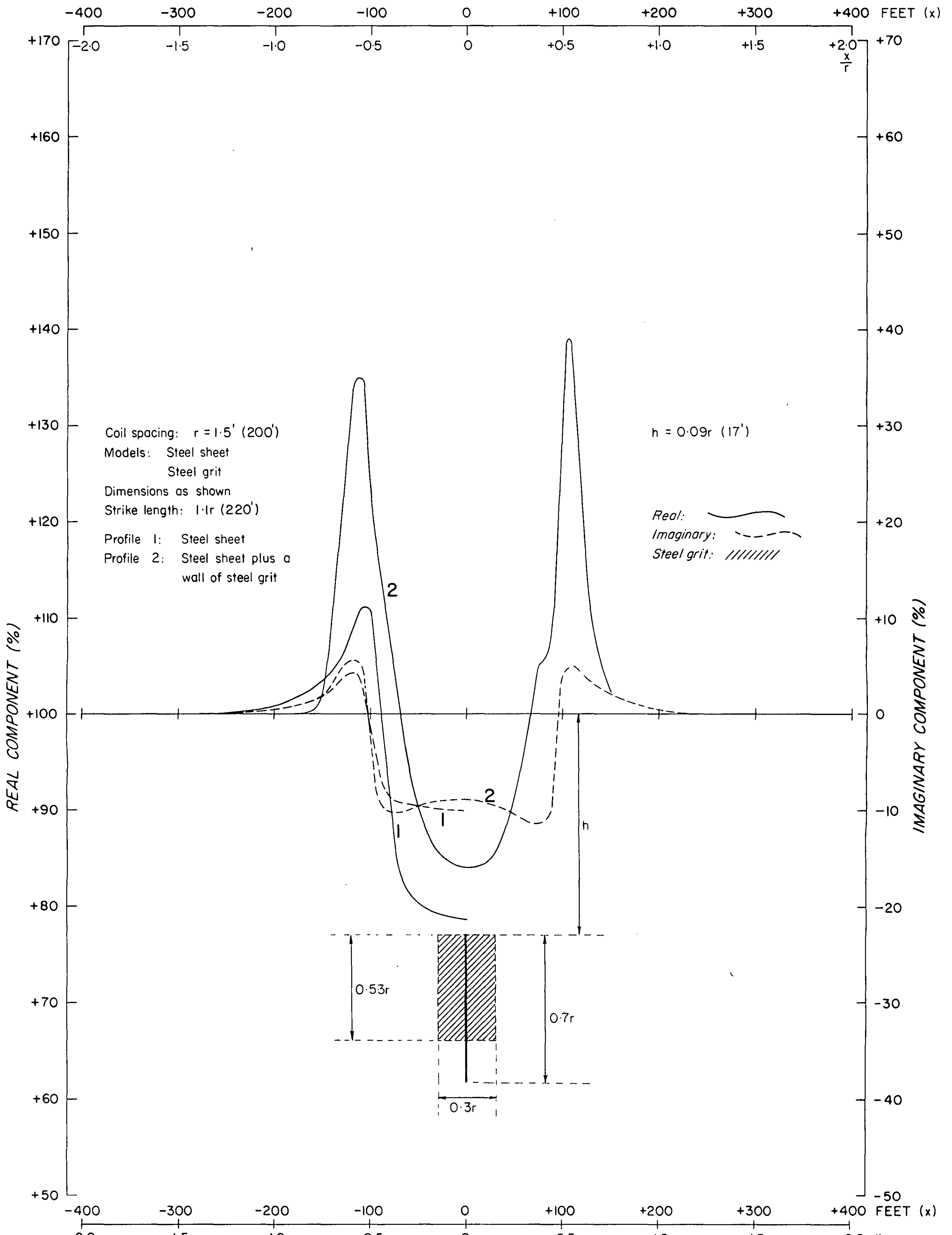
SLINGRAM MODEL TESTS

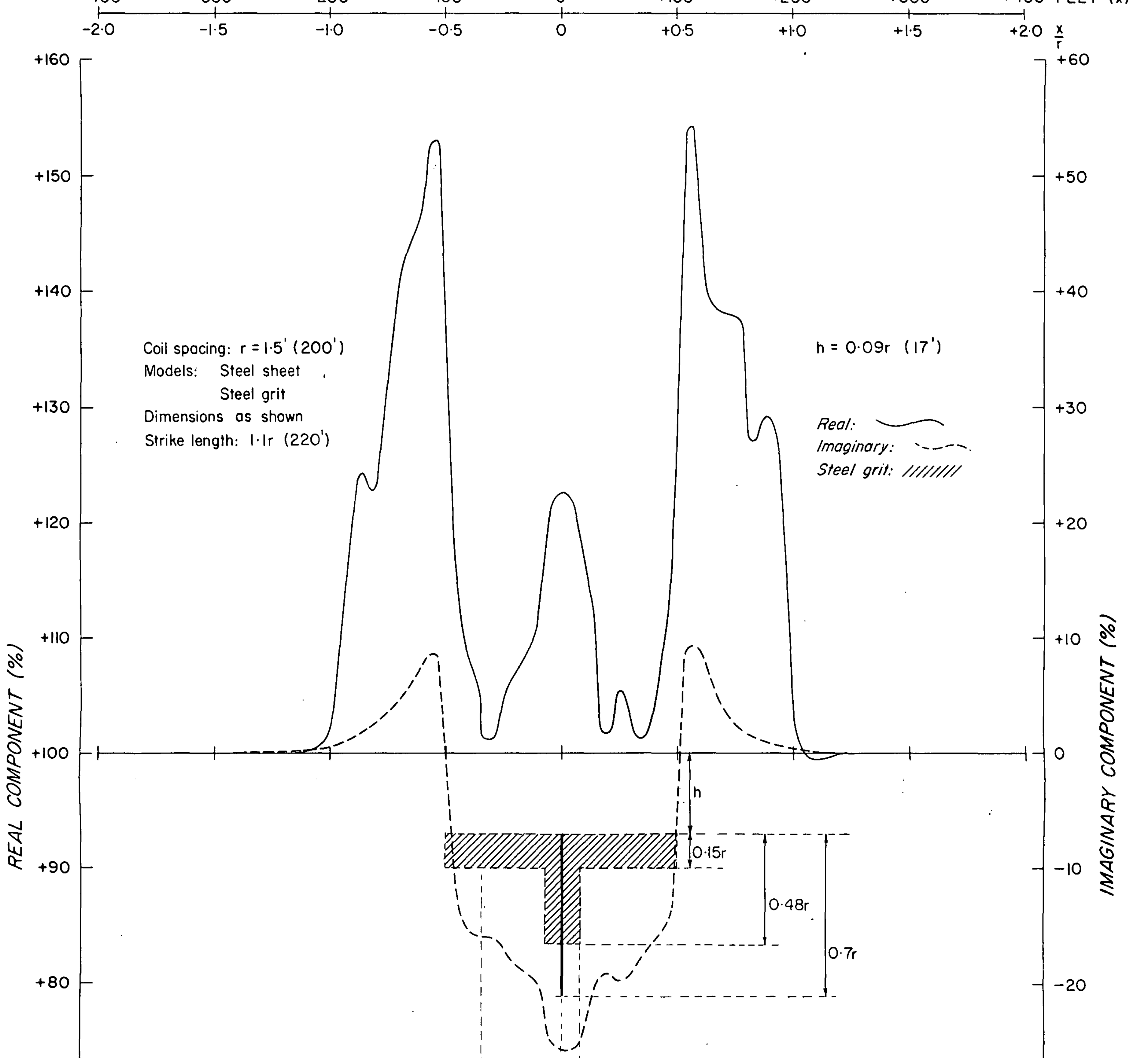
PROFILES OVER MAGNETIC AND CONDUCTING BODIES

PLATE 21

To accompany Record No. 1974/63

G29-195





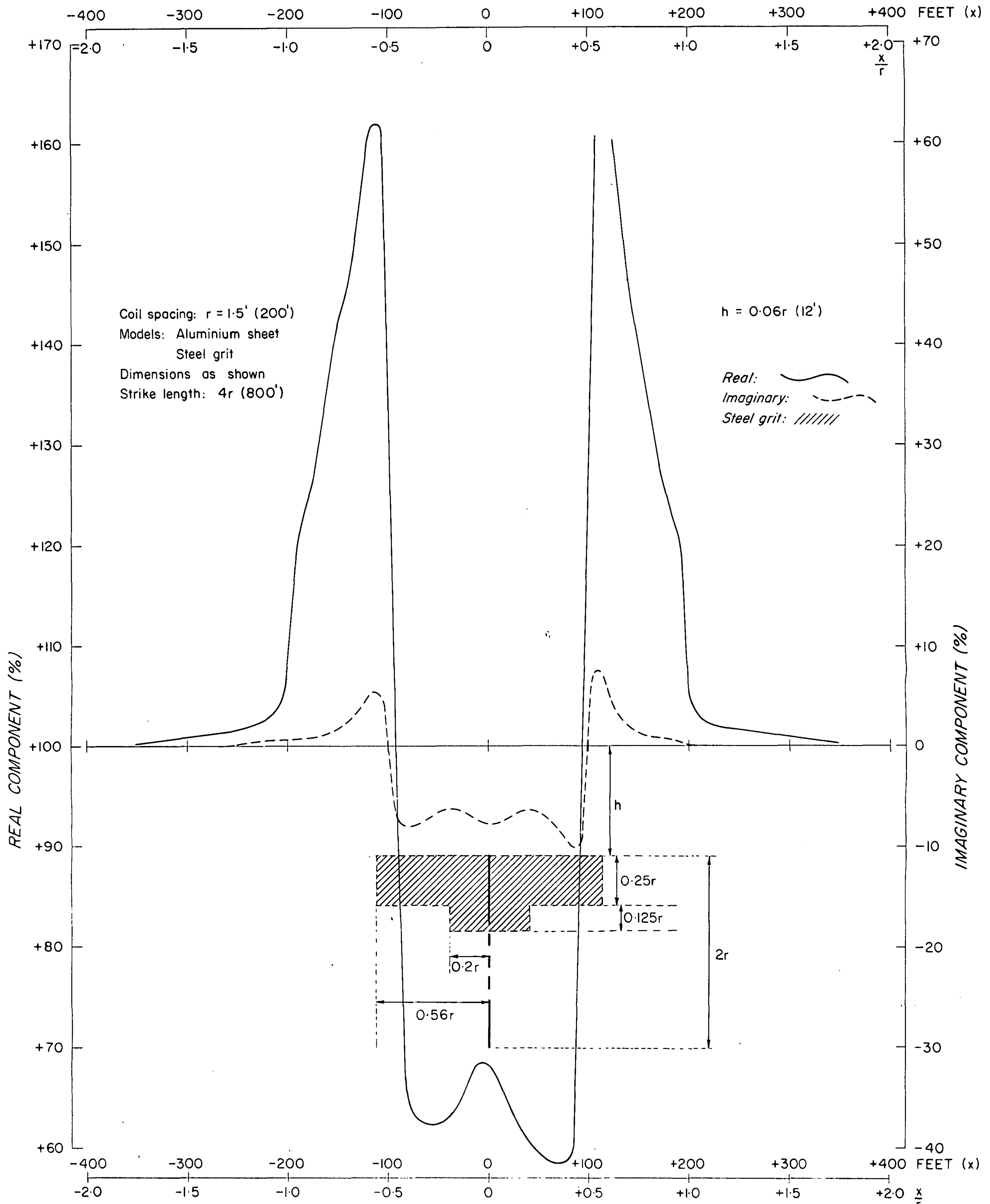
SLINGRAM MODEL TESTS

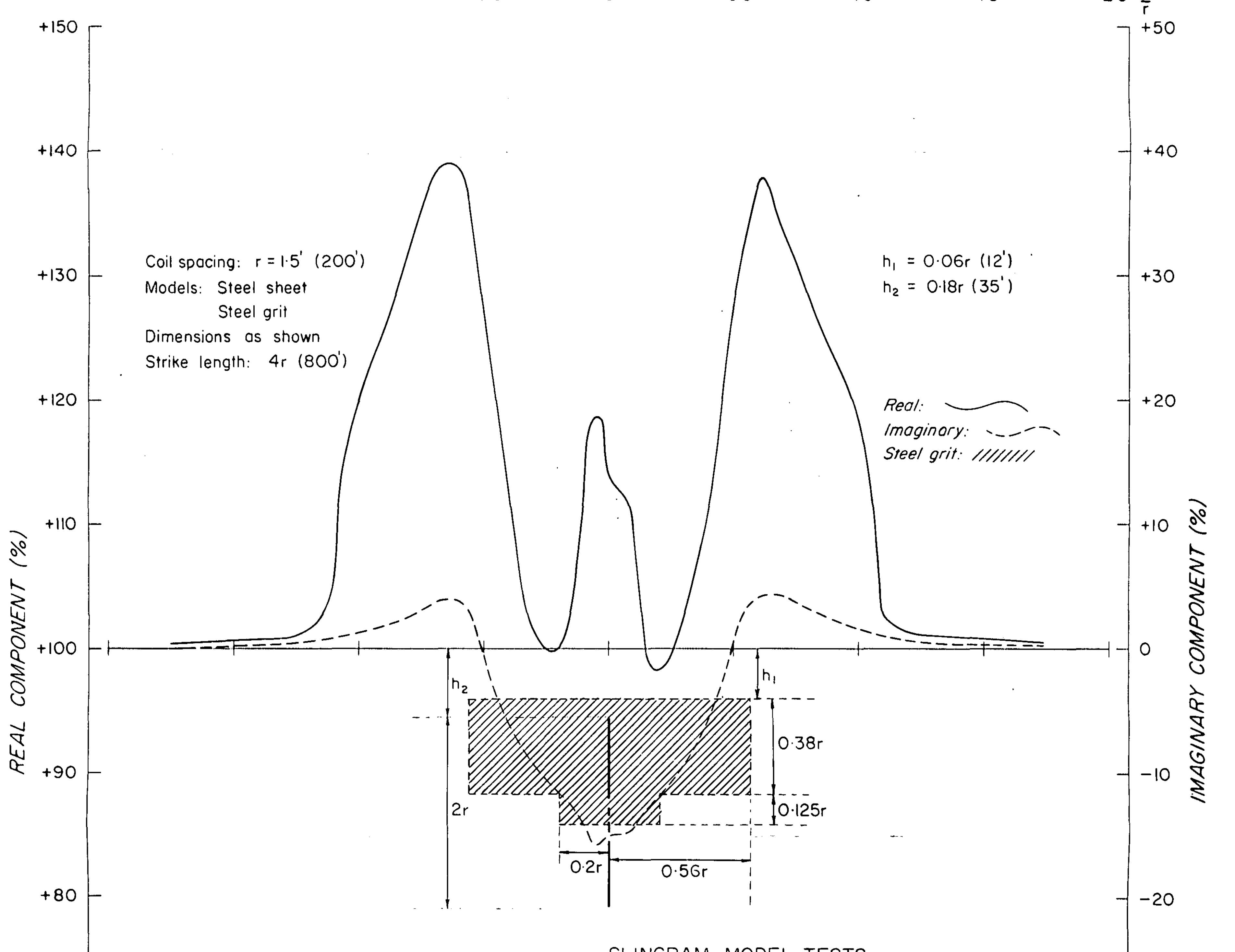
PROFILES OVER MAGNETIC AND CONDUCTING BODIES

PLATE 22

To accompany Record No. 1974/63

G29-196

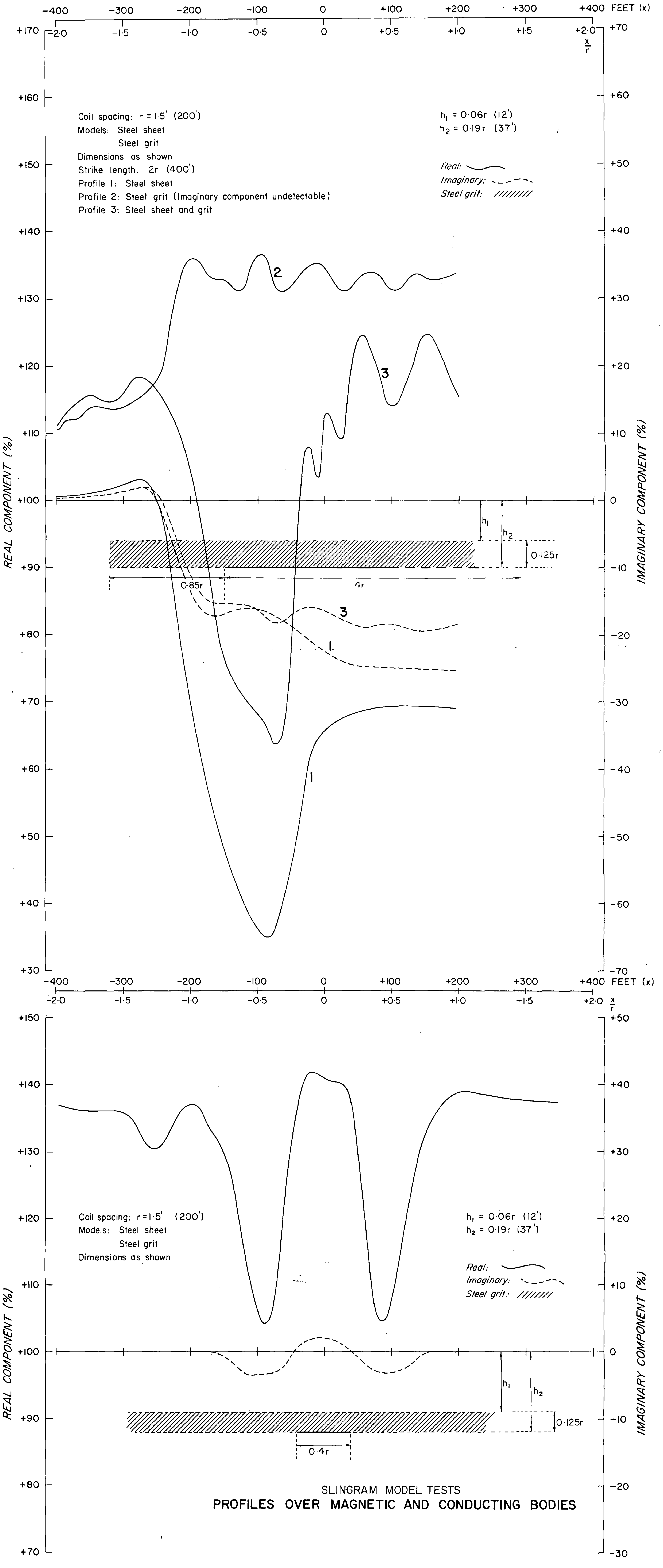




SLINGRAM MODEL TESTS

PROFILES OVER MAGNETIC AND CONDUCTING BODIES

PLATE 23



SLINGRAM MODEL TESTS

PROFILES OVER MAGNETIC AND CONDUCTING BODIES

PLATE 24

To accompany Record No.1974/63

G29-198