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# TWO EXPERIMENTAL SUPERCRITICAL LAMINAR-FLOW-CONTROL SWEPT-WING AIRFOILS

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## SUMMARY

Two supercritical laminar-flow-control airfoils were designed for a large-chord swept-wing experiment in the Langley 8-Foot Transonic Pressure Tunnel where suction was provided through most of the model surface for boundary-layer control. The first airfoil was derived from an existing full-chord laminar airfoil by extending the trailing edge and making changes in the two lower-surface concave regions. The second airfoil differed from the first one in that it was designed for testing without suction in the forward concave region of the lower surface. Differences between the first airfoil and the one from which it was derived as well as between the first and second airfoils are discussed. Airfoil coordinates and predicted pressure distributions for the design normal Mach number of 0.755 and section lift coefficient of 0.55 are given for the three airfoils.

## INTRODUCTION

A supercritical laminar-flow-control (LFC) airfoil experiment has been conducted in the Langley 8-Foot Transonic Pressure Tunnel (ref. 1). This large-chord airfoil test involved a contoured wind-tunnel liner (ref. 2) to simulate unbounded flow about an infinite-span wing with 23° sweep. References 3 and 4 describe supercritical LFC airfoils for swept wings which require suction through the surface to maintain a laminar boundary layer. The airfoil in reference 3, referred to as airfoil A in reference 5, was an early candidate for the experiment. A later candidate was airfoil 989C (ref. 4) which is referred to as airfoil B in reference 5; some advantages of airfoil B over airfoil A are lower suction requirements for full-chord laminar flow, a higher design Mach number, and a shorter pressure recovery to the trailing edge. Airfoils C and D were derived from airfoil B following the ideas of W. Pfenninger and P. J. Bobbitt of Langley Research Center. Airfoil B was modified at the trailing edge and in the lower-surface concave regions to derive airfoils C and D for the experiment. Airfoils C and D have essentially the same predicted off-design shock-formation characteristics as airfoil B (see ref. 5), and lift behavior with suction failure similar to that of airfoil A (see ref. 3). Suction distributions are given for airfoil C in references 1 and 6. Airfoil D differed from airfoil C only in the forward 20 percent of the lower surface where the concave region was redesigned for testing with no suction. The purpose of this paper is to compare the geometries and predicted design pressure distributions for airfoils B, C, and D and to document their coordinates.

## AIRFOIL ANALYSIS

Airfoils B, C, and D are shown in figure 1 and their design pressure distributions are compared in figures 2 and 3. All pressure distributions were predicted for the two-dimensional Mach number of 0.755 and lift coefficient of 0.55 (the design condition for the experiment, ref. 1). The two-dimensional design Reynolds number was 16.9 million (20 million streamwise) based on chord. The angle of attack at the design condition for airfoil B was -0.64° and for airfoils C and D, it was 0.51°. This 1.15° difference was due primarily to a 1.19° counter-clockwise rotation about the sharp trailing edge of airfoil B for alignment of the leading edge with the x axis before any airfoil modifications were made. The pressure distributions were predicted by a version of the Garabedian transonic analysis code (ref. 7), which allows a turbulent boundary layer to be started at different locations on the upper and lower surfaces. For airfoil B, the pressure distribution was predicted with no boundary layer (fig. 2), assuming that the laminar boundary layer would be kept thin over the entire surface by use of suction. Similarly, the predicted pressure distribution for airfoil C assumed a turbulent boundary layer only from $x/c = 0.96$ to the trailing edge on the upper surface and only from $x/c = 0.84$ to the trailing edge on the lower surface where the model did not have suction through the surface. For airfoil D, the turbulent boundary layer was again started at $x/c = 0.96$ on the upper surface, but it was started at $x/c = 0.19$ on the lower surface where transition was predicted, as will be discussed later. A 0.22° deflection of the 10.89-percent-chord trailing-edge flap was used to overcome the decambering effect of the lower-surface boundary layer for airfoil D and maintain the design lift coefficient (fig. 3).

The two concave regions on the lower surface of airfoil C had corners (abrupt changes in flow direction) which will be described later. These corners produced spikes in the pressure distribution when the boundary layer was laminar. Analysis of these pressure spikes required a computational method in which grid points could be very closely spaced in the regions of the corners. Since the spikes occurred in low-speed regions of the flow field, their shape could be calculated by an incompressible analysis. The panel method of Eppler, et al. (ref. 8) was used for this purpose with no boundary layer included. Small panels were slected in the regions of the concave corners to give resolution not possible in the Garabedian code. Of course, the incompressible pressure coefficient data had to be adjusted to account for the increase from the incompressible to the compressible pressure coefficient at the stagnation point. The Eppler-code results for the concave regions were shifted by this amount to blend with the Garabedian-code results for airfoil C.

## AIRFOIL COORDINATES

Nondimensional coordinates normal to the wing leading edge are given for airfoils B, C, and D in tables I, II, and III, respectively. Airfoils C and D were derived through a series of modifications to airfoil B (a full-chord-laminar airfoil designed by Pfenninger et al., ref. 4). The modifications involved extending the trailing edge and refairing the rear of the upper surface, redefining the concave regions on the lower surface, and smoothing the coordinates.

The trailing edge of airfoil B was extended by one percent of chord to reduce the high upper-surface pressure gradient (fig. 2) and lessen the chances of boundary-layer separation on the model and on the tunnel walls. The coordinates were then divided by the new chord length to rescale them. The trailing edge was thickened slightly to give the model a base thickness of 0.02 inches. The rear of the upper surface was faired in such a way that the slight concavity on airfoil B was eliminated for airfoil C.

There were two concave regions on the lower surface of airfoil B, as shown in figure 1. For airfoil C, each concave region was redefined as a series of corners (abrupt changes in slope), each rounded by an exponential function joined to two straight lines. Table IV gives the x/c location, turning angle, chordwise extent of rounding, and whether or not suction was required for each corner. These corners were defined to minimize the growth of Taylor-Görtler vortices by minimizing the extent of each concave region, as discussed in reference 4. There were two concave corners in the front region and two in the rear region where boundary-layer suction was provided in the model to prevent laminar separation. The two in the rear were each followed by a slightly convex turn (slightly negative turning angle, see Table IV). There were four additional concave corners in the rear region where no suction was provided. Spikes occurred in the pressure distribution for the first four concave corners for airfoil C (fig. 2), but not for the last four concave corners because, as mentioned earlier, a turbulent boundary layer was assumed for the calculation in the region behind x/c = 0.84.

Airfoil D (fig. 1) differed from airfoil C in the lower forward concave region between the leading edge and x/c = 0.20 and was designed for no suction in that region. The concavity there was less pronounced than that for airfoil C and had no abrupt corners because corners without suction could result in laminar separation. Pressure distributions for airfoils C and D are compared in figure 3. Note that the pressure distribution for airfoil C had a very steep pressure gradient between x/c = 0.15 and x/c = 0.20 on the lower surface to minimize the crossflow disturbance growth. Crossflow vortex amplification depends on both the steepness and the chordwise extent of the pressure gradient and can be minimized by minimizing the distance over which the pressure changes. The steep pressure gradient in the same region of airfoil D extended over a larger distance from x/c = 0.12 to x/c = 0.22, which made transition due to crossflow instability more likely. This was caused by the concave region being filled in to some extent to decrease the Taylor-Görtler disturbance growth by decreasing the curvature. To check for transition due to crossflow instability, laminar boundary layer and crossflow stability analyses (ref. 6) were performed using the CEBECI and MARIA computer codes with no suction for the lower surface of airfoil D. Transition was predicted at x/c = 0.19 based on a maximum logarithmic amplification ratio of $n_{max} = 9$ for the design condition.

Coordinates were smoothed to six-place accuracy for airfoils C and D to avoid errors in curve fits used in conjunction with the numerically-controlled milling machine. Six-place accuracy was especially important for coordinate points which were closely spaced to adequately define the concave corners and the sharp leading edge. Since the details of the shape were important, smoothing procedures, which would adjust coordinates over a large region, were not used. The smoothing was accomplished by adjusting small groups of coordinate points and requiring greatly magnified slope plots to be reasonably smooth. Plots of $\Delta y/\Delta x$ versus x/c were used over most of the airfoil with plots of $\Delta x/\Delta y$ versus y/c being used around the leading edge. Simple two-point slopes (centered between coordinate points) were used since they were more sensitive to coordinate adjustments than three-point slopes.

## CONCLUDING REMARKS

Coordinates have been given for the two airfoils (C and D) tested in the NASA supercritical laminar-flow-control swept-wing experiment as well as for airfoil B from which airfoil C was derived. The changes made to airfoil B to derive airfoil C have been discussed. The difference between airfoils C and D to allow testing with no suction in the lower forward region has been described. Predicted pressure distributions at the design condition of the experiment have been shown for all three airfoils.

## REFERENCES

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TABLE I.- AIRFOIL B COORDINATES

| upper surface | | lower surface | |
|---|---|---|---|
| x/c | y/c | x/c | y/c |
| -.00053 | .020050 | -.00053 | .020050 |
| -.0004 | .021670 | -.0004 | .019000 |
| 0. | .023135 | 0. | .018170 |
| .0005 | .024305 | .0005 | .017580 |
| .001 | .025225 | .001 | .017170 |
| .0015 | .025990 | .0025 | .016345 |
| .0025 | .027275 | .005 | .015452 |
| .004 | .028835 | .01 | .014292 |
| .006 | .030511 | .015 | .013390 |
| .008 | .031887 | .02 | .012580 |
| .01 | .033031 | .025 | .011800 |
| .011 | .033547 | .032887 | .010647 |
| .013 | .034495 | .041419 | .009446 |
| .015 | .035350 | .050885 | .008124 |
| .02 | .037193 | .061296 | .006705 |
| .025 | .038762 | .072735 | .005153 |
| .03 | .040139 | .085285 | .003412 |
| .035 | .041394 | .099393 | .001183 |
| .04 | .042534 | .114610 | -.002754 |
| .045 | .043598 | .129358 | -.008168 |
| .05 | .044579 | .143864 | -.013784 |
| .06 | .046383 | .158454 | -.020480 |
| .07 | .047984 | .171509 | -.028023 |
| .08 | .049444 | .18 | -.033001 |
| .09 | .050766 | .19 | -.037503 |
| .1 | .051991 | .2 | -.041009 |
| .11 | .053114 | .21 | -.043881 |
| .12 | .054163 | .22 | -.046340 |
| .13 | .055132 | .23 | -.048506 |
| .142632 | .056259 | .25 | -.052188 |
| .15 | .056876 | .275 | -.055870 |
| .175 | .058740 | .3 | -.058788 |
| .2 | .060317 | .325 | -.061096 |
| .225 | .061633 | .35 | -.062866 |
| .25 | .062727 | .375 | -.064170 |
| .275 | .063616 | .4 | -.065035 |
| .3 | .064322 | .425 | -.065481 |
| .325 | .064849 | .45 | -.065524 |
| .35 | .065215 | .475 | -.065159 |
| .375 | .065423 | .5 | -.064381 |
| .4 | .065476 | .525 | -.063172 |

TABLE I.- CONCLUDED

| upper surface | | lower surface | |
|---|---|---|---|
| x/c | y/c | x/c | y/c |
| .425 | .065384 | .55 | -.061502 |
| .45 | .065136 | .575 | -.059336 |
| .475 | .064749 | .597470 | -.056898 |
| .5 | .064205 | .614150 | -.054691 |
| .525 | .063519 | .630576 | -.052103 |
| .55 | .062675 | .646793 | -.048998 |
| .575 | .061669 | .662949 | -.045294 |
| .6 | .060499 | .679253 | -.041047 |
| .625 | .059146 | .695843 | -.036460 |
| .65 | .057608 | .712691 | -.031758 |
| .675 | .055853 | .729659 | -.027043 |
| .7 | .053879 | .746656 | -.022335 |
| .725 | .051641 | .763656 | -.017629 |
| .75 | .049119 | .780633 | -.012939 |
| .77 | .046825 | .797657 | -.008167 |
| .790034 | .044302 | .815050 | -.003389 |
| .804868 | .042226 | .833100 | .000784 |
| .819254 | .039969 | .851303 | .003520 |
| .833201 | .037597 | .868609 | .004810 |
| .846731 | .035126 | .884536 | .005343 |
| .859872 | .032396 | .899223 | .005610 |
| .872642 | .029463 | .912861 | .005766 |
| .885041 | .026530 | .925555 | .005813 |
| .897043 | .023693 | .937360 | .005745 |
| .908593 | .020975 | .948279 | .005515 |
| .919623 | .018437 | .958255 | .005092 |
| .930067 | .016063 | .967239 | .004514 |
| .939883 | .013855 | .975176 | .003785 |
| .949043 | .011847 | .981995 | .002946 |
| .957516 | .009926 | .987656 | .002112 |
| .965264 | .008203 | .992185 | .001367 |
| .972254 | .006614 | .995639 | .000771 |
| .978484 | .005160 | .998073 | .000342 |
| .983970 | .003826 | .999519 | .000086 |
| .988720 | .002649 | 1. | 0. |
| .992708 | .001676 | | |
| .995874 | .000947 | | |
| .998164 | .000435 | | |
| .999549 | .000125 | | |
| 1. | 0. | | |

TABLE II.- AIRFOIL C COORDINATES

| upper surface | | lower surface | |
|---|---|---|---|
| x/c | y/c | x/c | y/c |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| .000126 | .001024 | .000019 | -.000956 |
| .000389 | .002089 | .000201 | -.001824 |
| .000795 | .003181 | .000574 | -.002590 |
| .001349 | .004289 | .001170 | -.003259 |
| .002052 | .005406 | .002015 | -.003848 |
| .002910 | .006526 | .003121 | -.004375 |
| .003922 | .007646 | .004484 | -.004868 |
| .005088 | .008757 | .006098 | -.005328 |
| .006406 | .009849 | .007967 | -.005755 |
| .007888 | .010911 | .010103 | -.006161 |
| .009549 | .011946 | .012503 | -.006569 |
| .011397 | .012964 | .015157 | -.006988 |
| .013434 | .013967 | .018058 | -.007417 |
| .015651 | .014950 | .021208 | -.007857 |
| .018055 | .015916 | .024596 | -.008306 |
| .020650 | .016867 | .028212 | -.008760 |
| .023433 | .017810 | .032059 | -.009223 |
| .026399 | .018749 | .035891 | -.009673 |
| .029546 | .019678 | .036881 | -.009789 |
| .032873 | .020598 | .038861 | -.010021 |
| .036384 | .021511 | .042822 | -.010484 |
| .040071 | .022420 | .046782 | -.010948 |
| .043934 | .023324 | .050743 | -.011411 |
| .047966 | .024221 | .054703 | -.011874 |
| .052169 | .025110 | .058663 | -.012338 |
| .056541 | .025989 | .062624 | -.012801 |
| .061081 | .026859 | .066584 | -.013264 |
| .065787 | .027723 | .070545 | -.013728 |
| .070656 | .028577 | .074505 | -.014191 |
| .075686 | .029423 | .078465 | -.014654 |
| .080875 | .030257 | .082426 | -.015118 |
| .086223 | .031082 | .086386 | -.015581 |
| .091725 | .031897 | .090347 | -.016045 |
| .097378 | .032701 | .094307 | -.016508 |
| .103182 | .033494 | .098267 | -.016971 |
| .109136 | .034277 | .100990 | -.017290 |
| .115235 | .035050 | .103465 | -.017588 |
| .121473 | .035810 | .105446 | -.017869 |
| .127851 | .036557 | .106931 | -.018170 |
| .134371 | .037292 | .108416 | -.018584 |

TABLE II.- CONTINUED

| upper surface | | lower surface | |
|---|---|---|---|
| x/c | y/c | x/c | y/c |
| .141029 | .038014 | .110396 | -.019250 |
| .147817 | .038723 | .113366 | -.020315 |
| .154734 | .039418 | .117327 | -.021743 |
| .161778 | .040100 | .121782 | -.023350 |
| .168950 | .040768 | .127835 | -.025535 |
| .176244 | .041423 | .135118 | -.028162 |
| .183656 | .042061 | .140594 | -.030138 |
| .191183 | .042684 | .144554 | -.031566 |
| .198823 | .043292 | .147525 | -.032639 |
| .206572 | .043884 | .150000 | -.033538 |
| .214430 | .044459 | .151980 | -.034290 |
| .222392 | .045019 | .153465 | -.034930 |
| .230455 | .045561 | .154950 | -.035668 |
| .238617 | .046088 | .156436 | -.036474 |
| .246871 | .046599 | .158416 | -.037584 |
| .255218 | .047093 | .160891 | -.038982 |
| .263652 | .047570 | .164067 | -.040777 |
| .272172 | .048030 | .167228 | -.042563 |
| .280774 | .048470 | .170464 | -.044392 |
| .289453 | .048892 | .176424 | -.047725 |
| .298206 | .049295 | .182162 | -.050623 |
| .307031 | .049679 | .187889 | -.053088 |
| .315924 | .050045 | .193737 | -.055206 |
| .324881 | .050391 | .199755 | -.057071 |
| .333900 | .050719 | .205949 | -.058755 |
| .342975 | .051028 | .212309 | -.060304 |
| .352105 | .051318 | .218818 | -.061743 |
| .361284 | .051588 | .225460 | -.063084 |
| .370509 | .051839 | .232232 | -.064334 |
| .379778 | .052069 | .239130 | -.065502 |
| .389086 | .052279 | .246151 | -.066598 |
| .398431 | .052469 | .253282 | -.067625 |
| .407807 | .052639 | .260515 | -.068583 |
| .417210 | .052788 | .267853 | -.069479 |
| .426639 | .052917 | .275295 | -.070318 |
| .436089 | .053025 | .282831 | -.071101 |
| .445557 | .053111 | .290451 | -.071830 |
| .455040 | .053175 | .298158 | -.072503 |
| .464532 | .053218 | .305950 | -.073124 |
| .474029 | .053239 | .313817 | -.073693 |
| .483529 | .053238 | .321752 | -.074210 |

TABLE II.- CONTINUED

| upper surface | | lower surface | |
|---|---|---|---|
| x/c | y/c | x/c | y/c |
| .493030 | .053215 | .329758 | -.074677 |
| .502527 | .053170 | .337834 | -.075096 |
| .512015 | .053104 | .345971 | -.075465 |
| .521490 | .053015 | .354164 | -.075786 |
| .530948 | .052903 | .362413 | -.076060 |
| .540387 | .052769 | .370714 | -.076286 |
| .549803 | .052613 | .379061 | -.076464 |
| .559194 | .052435 | .387448 | -.076593 |
| .568553 | .052235 | .395874 | -.076674 |
| .577880 | .052012 | .404340 | -.076707 |
| .587168 | .051766 | .412837 | -.076692 |
| .596415 | .051498 | .421361 | -.076628 |
| .605618 | .051207 | .429910 | -.076518 |
| .614772 | .050892 | .438482 | -.076359 |
| .623874 | .050553 | .447071 | -.076151 |
| .632921 | .050191 | .455672 | -.075894 |
| .641910 | .049806 | .464283 | -.075589 |
| .650837 | .049395 | .472903 | -.075234 |
| .659698 | .048960 | .481526 | -.074830 |
| .668491 | .048501 | .490147 | -.074375 |
| .677212 | .048018 | .498762 | -.073868 |
| .685858 | .047511 | .507372 | -.073310 |
| .694427 | .046979 | .515971 | -.072699 |
| .702914 | .046424 | .524552 | -.072036 |
| .711315 | .045842 | .533115 | -.071319 |
| .719626 | .045233 | .541656 | -.070548 |
| .727844 | .044595 | .550174 | -.069721 |
| .735968 | .043930 | .558658 | -.068839 |
| .743999 | .043238 | .567107 | -.067899 |
| .751931 | .042519 | .575514 | -.066899 |
| .759761 | .041771 | .583873 | -.065836 |
| .767487 | .040996 | .592180 | -.064704 |
| .775103 | .040192 | .600430 | -.063497 |
| .782607 | .039358 | .608620 | -.062206 |
| .789998 | .038493 | .616747 | -.060820 |
| .797275 | .037591 | .624811 | -.059324 |
| .804442 | .036651 | .632822 | -.057702 |
| .811497 | .035676 | .640795 | -.055943 |
| .818442 | .034665 | .648750 | -.054040 |
| .825269 | .033620 | .656709 | -.051988 |
| .831976 | .032537 | .664701 | -.049797 |

TABLE II.- CONTINUED

| upper surface | | lower surface | |
|---|---|---|---|
| x/c | y/c | x/c | y/c |
| .838567 | .031409 | .672750 | -.047489 |
| .845049 | .030237 | .680868 | -.045093 |
| .851485 | .029011 | .689604 | -.042483 |
| .856436 | .028031 | .698515 | -.039806 |
| .861386 | .027025 | .704455 | -.038018 |
| .866337 | .026004 | .714356 | -.035038 |
| .871287 | .024974 | .724257 | -.032057 |
| .876238 | .023941 | .734158 | -.029077 |
| .881188 | .022906 | .744059 | -.026097 |
| .886139 | .021871 | .753960 | -.023117 |
| .891089 | .020837 | .763861 | -.020137 |
| .896040 | .019802 | .773762 | -.017156 |
| .900990 | .018767 | .783663 | -.014176 |
| .905941 | .017733 | .793564 | -.011196 |
| .910891 | .016698 | .801980 | -.008663 |
| .915842 | .015663 | .807921 | -.006876 |
| .920792 | .014630 | .811961 | -.005661 |
| .925743 | .013597 | .815130 | -.004709 |
| .930693 | .012565 | .817110 | -.004114 |
| .935644 | .011535 | .818694 | -.003641 |
| .940594 | .010505 | .819882 | -.003298 |
| .945545 | .009476 | .821070 | -.002997 |
| .950495 | .008449 | .822258 | -.002750 |
| .955446 | .007422 | .823447 | -.002540 |
| .960396 | .006397 | .825031 | -.002280 |
| .965347 | .005374 | .826724 | -.002006 |
| .970297 | .004353 | .828699 | -.001686 |
| .975248 | .003335 | .830392 | -.001412 |
| .980198 | .002318 | .832085 | -.001137 |
| .985149 | .001303 | .833778 | -.000860 |
| .990099 | .000290 | .835471 | -.000582 |
| .995050 | -.000721 | .837447 | -.000257 |
| 1.000000 | -.001730 | .839140 | .000021 |
| | | .840724 | .000277 |
| | | .841912 | .000456 |
| | | .843100 | .000602 |
| | | .844288 | .000701 |
| | | .845476 | .000766 |
| | | .847060 | .000839 |
| | | .848753 | .000911 |
| | | .850729 | .000993 |

TABLE II.- CONCLUDED

| upper surface | | lower surface | |
|---|---|---|---|
| x/c | y/c | x/c | y/c |
| | | .852422 | .001063 |
| | | .854115 | .001135 |
| | | .855808 | .001207 |
| | | .857501 | .001280 |
| | | .859476 | .001367 |
| | | .861386 | .001452 |
| | | .863366 | .001542 |
| | | .866337 | .001675 |
| | | .871287 | .001898 |
| | | .876238 | .002121 |
| | | .881188 | .002344 |
| | | .886139 | .002565 |
| | | .889109 | .002691 |
| | | .891089 | .002763 |
| | | .893069 | .002818 |
| | | .896040 | .002881 |
| | | .899010 | .002938 |
| | | .902970 | .003011 |
| | | .907921 | .003101 |
| | | .914851 | .003216 |
| | | .921782 | .003291 |
| | | .926733 | .003289 |
| | | .930693 | .003235 |
| | | .934653 | .003128 |
| | | .939604 | .002929 |
| | | .946535 | .002571 |
| | | .953465 | .002174 |
| | | .958416 | .001882 |
| | | .962376 | .001647 |
| | | .965347 | .001462 |
| | | .968317 | .001263 |
| | | .970297 | .001118 |
| | | .972277 | .000958 |
| | | .975248 | .000699 |
| | | .980198 | .000240 |
| | | .985149 | -.000229 |
| | | .988119 | -.000521 |
| | | .990099 | -.000732 |
| | | .992079 | -.000965 |
| | | .995050 | -.001342 |
| | | 1.000000 | -.001986 |

TABLE III.- AIRFOIL D COORDINATES

| upper surface | | lower surface | |
|---|---|---|---|
| x/c | y/c | x/c | y/c |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| .000126 | .001024 | .000019 | -.000956 |
| .000389 | .002089 | .000201 | -.001824 |
| .000795 | .003181 | .000574 | -.002590 |
| .001349 | .004289 | .001170 | -.003259 |
| .002052 | .005406 | .002015 | -.003848 |
| .002910 | .006526 | .003121 | -.004375 |
| .003922 | .007646 | .004484 | -.004868 |
| .005088 | .008757 | .006098 | -.005328 |
| .006406 | .009849 | .008000 | -.005780 |
| .007888 | .010911 | .011000 | -.006376 |
| .009549 | .011946 | .015000 | -.007115 |
| .011397 | .012964 | .020000 | -.008030 |
| .013434 | .013967 | .025000 | -.008945 |
| .015651 | .014950 | .030000 | -.009860 |
| .018055 | .015916 | .035000 | -.010775 |
| .020650 | .016867 | .040000 | -.011690 |
| .023433 | .017810 | .045000 | -.012605 |
| .026399 | .018749 | .050000 | -.013520 |
| .029546 | .019678 | .055000 | -.014435 |
| .032873 | .020598 | .060000 | -.015350 |
| .036384 | .021511 | .065000 | -.016265 |
| .040071 | .022420 | .070000 | -.017180 |
| .043934 | .023324 | .075000 | -.018099 |
| .047966 | .024221 | .080000 | -.019030 |
| .052169 | .025110 | .085000 | -.019984 |
| .056541 | .025989 | .090000 | -.020980 |
| .061081 | .026859 | .095000 | -.022050 |
| .065787 | .027723 | .100000 | -.023200 |
| .070656 | .028577 | .105000 | -.024440 |
| .075686 | .029423 | .110000 | -.025770 |
| .080875 | .030257 | .115000 | -.027190 |
| .086223 | .031082 | .120000 | -.028690 |
| .091725 | .031897 | .125000 | -.030270 |
| .097378 | .032701 | .130000 | -.031923 |
| .103182 | .033494 | .135000 | -.033640 |
| .109136 | .034277 | .140000 | -.035410 |
| .115235 | .035050 | .145000 | -.037225 |
| .121473 | .035810 | .150000 | -.039072 |

TABLE III.- CONTINUED

| upper surface | | lower surface | |
|---|---|---|---|
| x/c | y/c | x/c | y/c |
| .127851 | .036557 | .155000 | -.040930 |
| .134371 | .037292 | .160000 | -.042790 |
| .141029 | .038014 | .165000 | -.044650 |
| .147817 | .038723 | .170000 | -.046510 |
| .154734 | .039418 | .175000 | -.048370 |
| .161778 | .040100 | .179500 | -.050044 |
| .168950 | .040768 | .184000 | -.051714 |
| .176244 | .041423 | .188500 | -.053366 |
| .183656 | .042061 | .193737 | -.055206 |
| .191183 | .042684 | .199755 | -.057071 |
| .198823 | .043292 | .205949 | -.058755 |
| .206572 | .043884 | .212309 | -.060304 |
| .214430 | .044459 | .218818 | -.061743 |
| .222392 | .045019 | .225460 | -.063084 |
| .230455 | .045561 | .232232 | -.064334 |
| .238617 | .046088 | .239130 | -.065502 |
| .246871 | .046599 | .246151 | -.066598 |
| .255218 | .047093 | .253282 | -.067625 |
| .263652 | .047570 | .260515 | -.068583 |
| .272172 | .048030 | .267853 | -.069479 |
| .280774 | .048470 | .275295 | -.070318 |
| .289453 | .048892 | .282831 | -.071101 |
| .298206 | .049295 | .290451 | -.071830 |
| .307031 | .049679 | .298158 | -.072503 |
| .315924 | .050045 | .305950 | -.073124 |
| .324881 | .050391 | .313817 | -.073693 |
| .333900 | .050719 | .321752 | -.074210 |
| .342975 | .051028 | .329758 | -.074677 |
| .352105 | .051318 | .337834 | -.075096 |
| .361284 | .051588 | .345971 | -.075465 |
| .370509 | .051839 | .354164 | -.075786 |
| .379778 | .052069 | .362413 | -.076060 |
| .389086 | .052279 | .370714 | -.076286 |
| .398431 | .052469 | .379061 | -.076464 |
| .407807 | .052639 | .387448 | -.076593 |
| .417210 | .052788 | .395874 | -.076674 |
| .426639 | .052917 | .404340 | -.076707 |
| .436089 | .053025 | .412837 | -.076692 |
| .445557 | .053111 | .421361 | -.076628 |

TABLE III.- CONTINUED

| upper surface | | lower surface | |
|---|---|---|---|
| x/c | y/c | x/c | y/c |
| .455040 | .053175 | .429910 | -.076518 |
| .464532 | .053218 | .438482 | -.076359 |
| .474029 | .053239 | .447071 | -.076151 |
| .483529 | .053238 | .455672 | -.075894 |
| .493030 | .053215 | .464283 | -.075589 |
| .502527 | .053170 | .472903 | -.075234 |
| .512015 | .053104 | .481526 | -.074830 |
| .521490 | .053015 | .490147 | -.074375 |
| .530948 | .052903 | .498762 | -.073868 |
| .540387 | .052769 | .507372 | -.073310 |
| .549803 | .052613 | .515971 | -.072699 |
| .559194 | .052435 | .524552 | -.072036 |
| .568553 | .052235 | .533115 | -.071319 |
| .577880 | .052012 | .541656 | -.070548 |
| .587168 | .051766 | .550174 | -.069721 |
| .596415 | .051498 | .558658 | -.068839 |
| .605618 | .051207 | .567107 | -.067899 |
| .614772 | .050892 | .575514 | -.066899 |
| .623874 | .050553 | .583873 | -.065836 |
| .632921 | .050191 | .592180 | -.064704 |
| .641910 | .049806 | .600430 | -.063497 |
| .650837 | .049395 | .608620 | -.062206 |
| .659698 | .048960 | .616747 | -.060820 |
| .668491 | .048501 | .624811 | -.059324 |
| .677212 | .048018 | .632822 | -.057702 |
| .685858 | .047511 | .640795 | -.055943 |
| .694427 | .046979 | .648750 | -.054040 |
| .702914 | .046424 | .656709 | -.051988 |
| .711315 | .045842 | .664701 | -.049797 |
| .719626 | .045233 | .672750 | -.047489 |
| .727844 | .044595 | .680868 | -.045093 |
| .735968 | .043930 | .689604 | -.042483 |
| .743999 | .043238 | .698515 | -.039806 |
| .751931 | .042519 | .704455 | -.038018 |
| .759761 | .041771 | .714356 | -.035038 |
| .767487 | .040996 | .724257 | -.032057 |
| .775103 | .040192 | .734158 | -.029077 |
| .782607 | .039358 | .744059 | -.026097 |
| .789998 | .038493 | .753960 | -.023117 |

TABLE III.- CONCLUDED

| upper surface | | lower surface | |
|---|---|---|---|
| x/c | y/c | x/c | y/c |
| .797275 | .037591 | .763861 | -.020137 |
| .804442 | .036651 | .773762 | -.017156 |
| .811497 | .035676 | .783663 | -.014176 |
| .818442 | .034665 | .793564 | -.011196 |
| .825269 | .033620 | .801980 | -.008663 |
| .831976 | .032537 | .807921 | -.006876 |
| .838567 | .031409 | .811961 | -.005661 |
| .845049 | .030237 | .817110 | -.004114 |
| .851485 | .029011 | .825031 | -.002280 |
| .856436 | .028031 | .828699 | -.001686 |
| .861386 | .027025 | .835471 | -.000582 |
| .866337 | .026004 | .839140 | .000021 |
| .871287 | .024974 | .847060 | .000839 |
| .876238 | .023941 | .850729 | .000993 |
| .881188 | .022906 | .857501 | .001280 |
| .886139 | .021871 | .861386 | .001452 |
| .891089 | .020837 | .866337 | .001675 |
| .896040 | .019802 | .871287 | .001898 |
| .900990 | .018767 | .876238 | .002121 |
| .905941 | .017733 | .881188 | .002344 |
| .910891 | .016698 | .886139 | .002565 |
| .915842 | .015663 | .896040 | .002881 |
| .920792 | .014630 | .902970 | .003011 |
| .925743 | .013597 | .907921 | .003101 |
| .930693 | .012565 | .914851 | .003216 |
| .935644 | .011535 | .921782 | .003291 |
| .940594 | .010505 | .926733 | .003289 |
| .945545 | .009476 | .934653 | .003128 |
| .950495 | .008449 | .939604 | .002929 |
| .955446 | .007422 | .946535 | .002571 |
| .960396 | .006397 | .953465 | .002174 |
| .965347 | .005374 | .958416 | .001882 |
| .970297 | .004353 | .965347 | .001462 |
| .975248 | .003335 | .975248 | .000699 |
| .980198 | .002318 | .980198 | .000240 |
| .985149 | .001303 | .985149 | -.000229 |
| .990099 | .000290 | .995050 | -.001342 |
| .995050 | -.000721 | 1.000000 | -.001986 |
| 1.000000 | -.001730 | | |

TABLE IV.- LOWER SURFACE TURNS FOR AIRFOIL C

| Location x/c | Turning Angle, deg. | Extent $\Delta x/c$ | Suction Required |
|---|---|---|---|
| .107 | 13.2 | .011 | yes |
| .153 | 9.6 | .010 | yes |
| .821 | 7.6 | .007 | yes |
| .832 | -0.2 | .013 | no |
| .843 | 7.0 | .007 | yes |
| .854 | -0.2 | .013 | no |
| .891 | 1.5 | .010 | no |
| .931 | 4.5 | .059 | no |
| .970 | 2.0 | .020 | no |
| .990 | 2.0 | .010 | no |

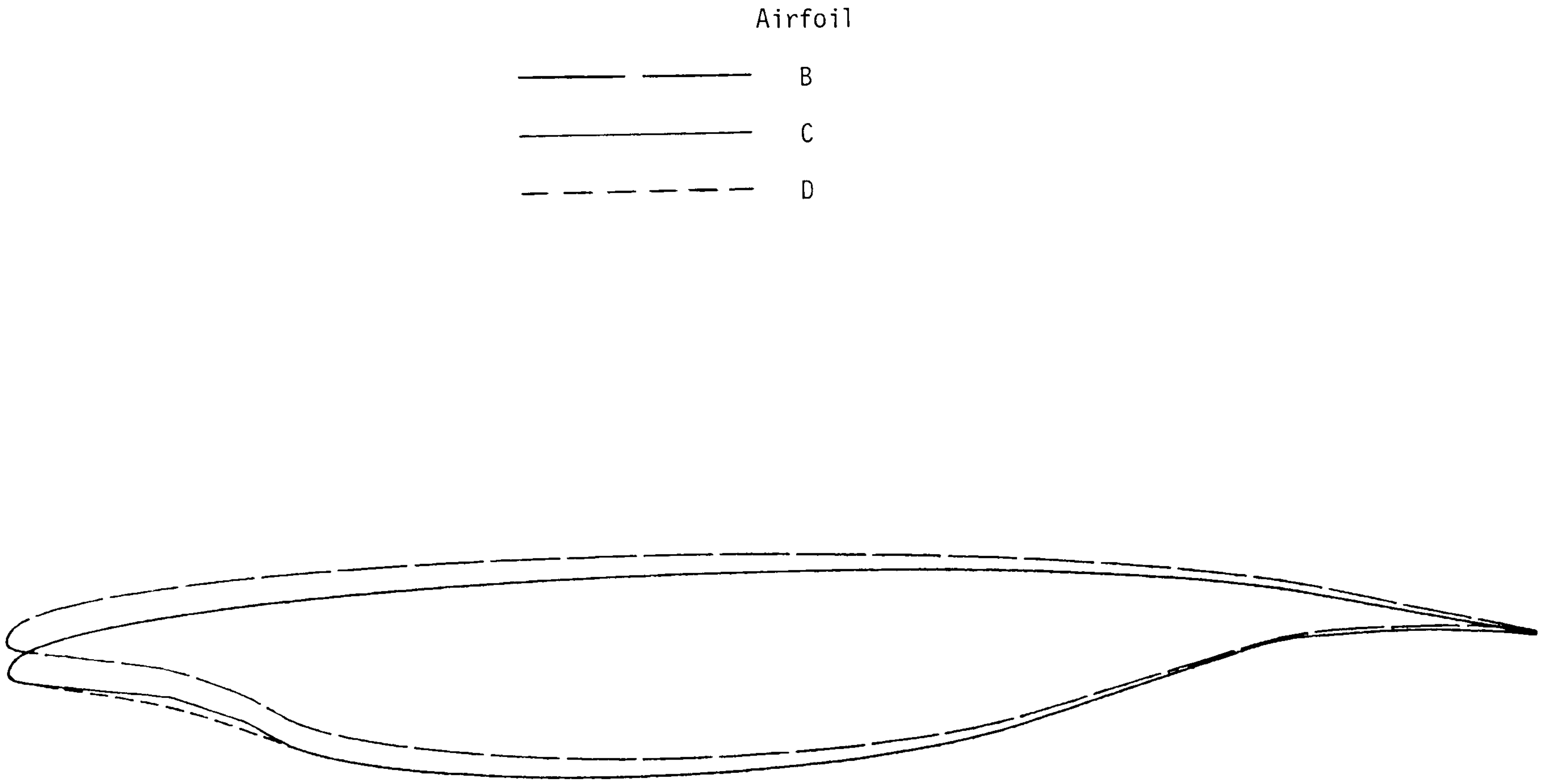


Figure 1. Comparison of three supercritical laminar-flow-control airfoils.

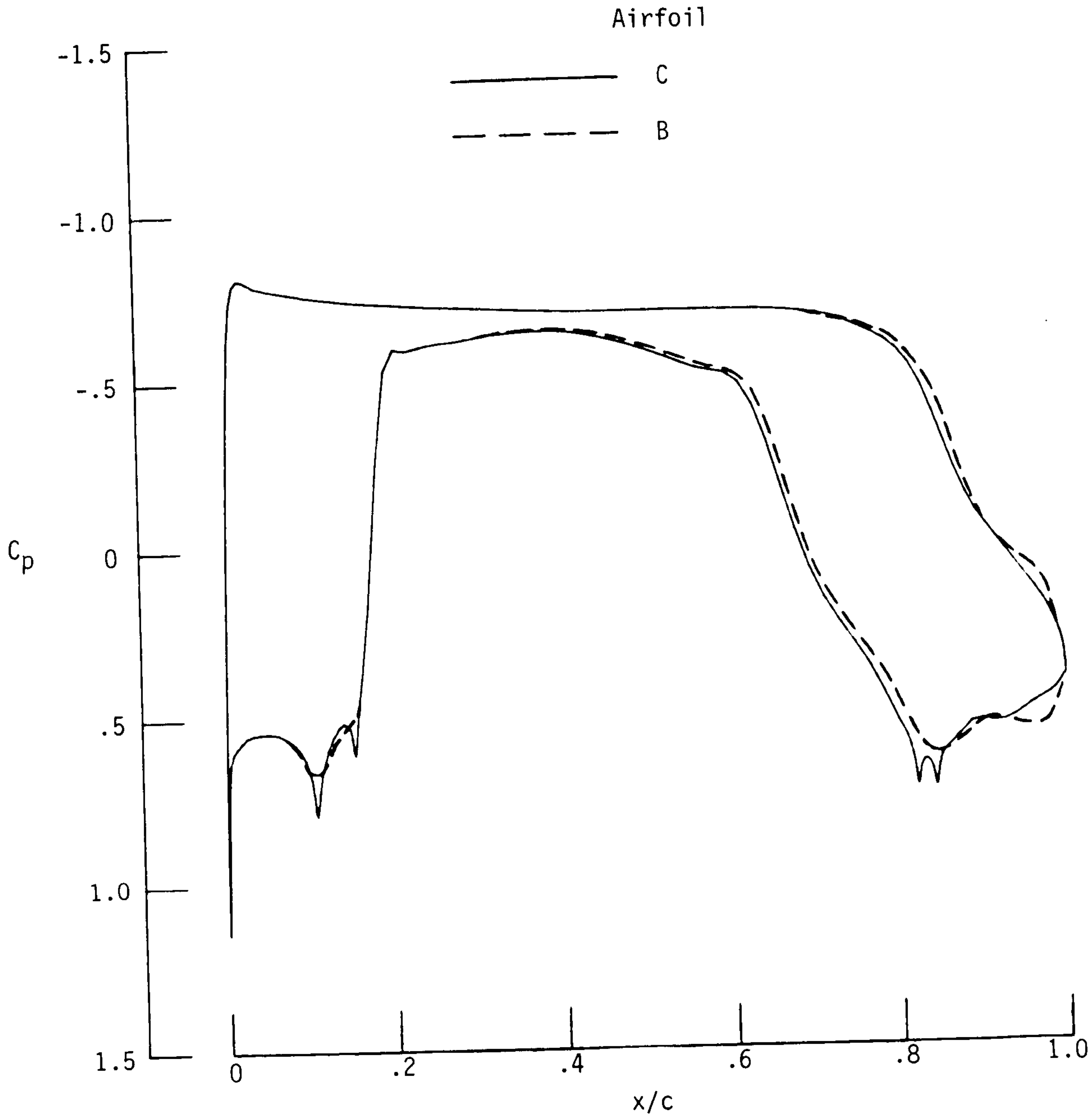


Figure 2. Comparison of predicted pressure distributions of airfoils B and C at a Mach number of 0.755, a lift coefficient of 0.55, and a Reynolds number of 16.9 X $10^6$.

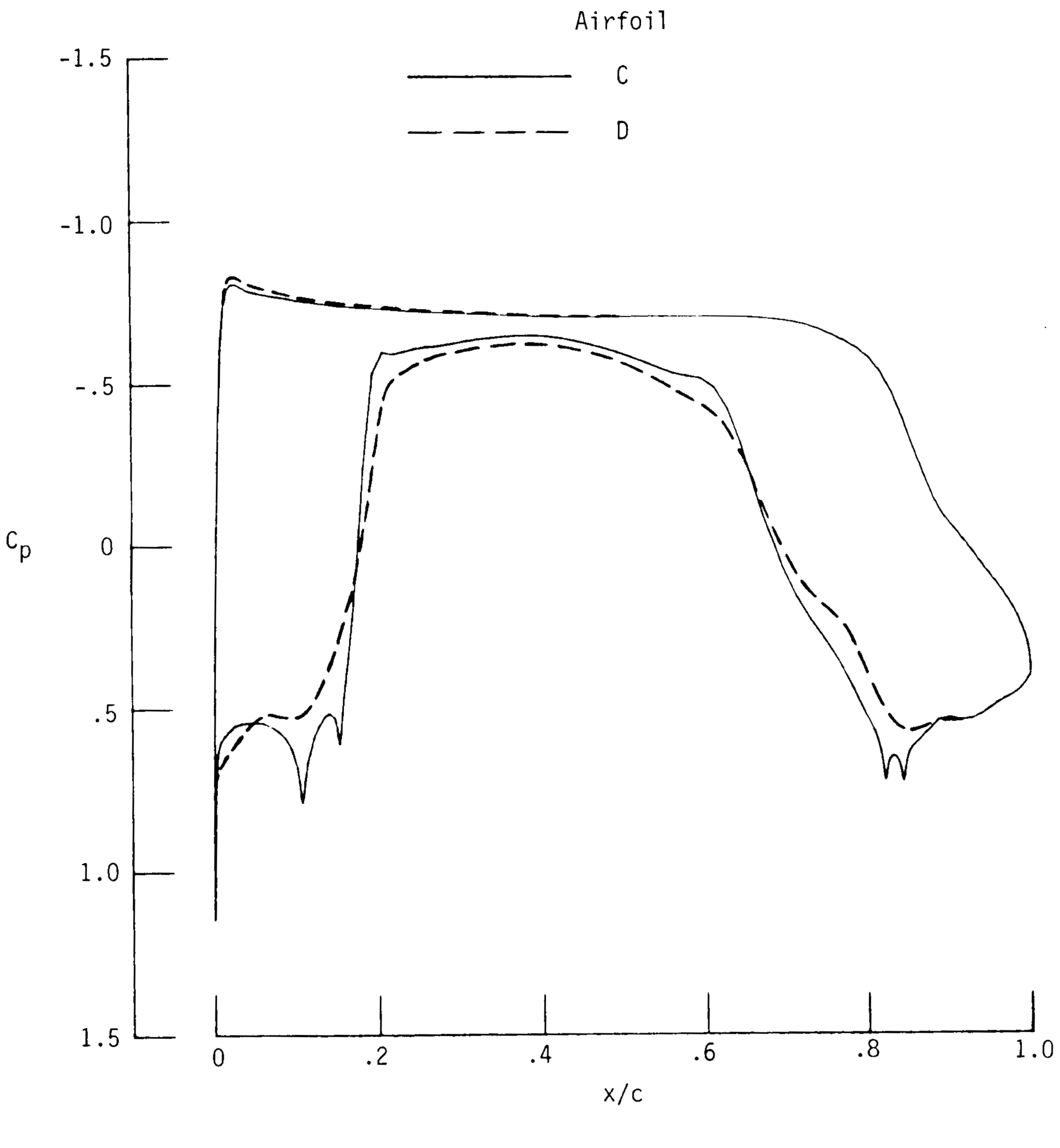


Figure 3. Comparison of predicted pressure distributions of airfoils C and D at a Mach number of 0.755, a lift coefficient of 0.55, and a Reynolds number of 16.9 X $10^6$.

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15. Supplementary Notes

16. Abstract

Two supercritical laminar-flow-control airfoils were designed for a large-chord swept-wing experiment in the Langley 8-Foot Transonic Pressure Tunnel where suction was provided through most of the model surface for boundary-layer control. The first airfoil was derived from an existing full-chord laminar airfoil by extending the trailing edge and making changes in the two lower-surface concave regions. The second airfoil differed from the first one in that it was designed for testing without suction in the forward concave region of the lower surface. Differences between the first airfoil and the one from which it was derived as well as between the first and second airfoils are discussed. Airfoil coordinates and predicted pressure distributions for the design normal Mach number of 0.755 and section lift coefficient of 0.55 are given for the three airfoils.

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