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(54) RESONATOR WITH RETENTION RIBS

(76) Inventors: **Jessie A. Knight**, Stoughton, WI (US); **Michael J. Connor**, Stoughton, WI (US)

Correspondence Address:
ANDRUS, SCEALES, STARKE & SAWALL, LLP
100 EAST WISCONSIN AVENUE, SUITE 1100
MILWAUKEE, WI 53202 (US)

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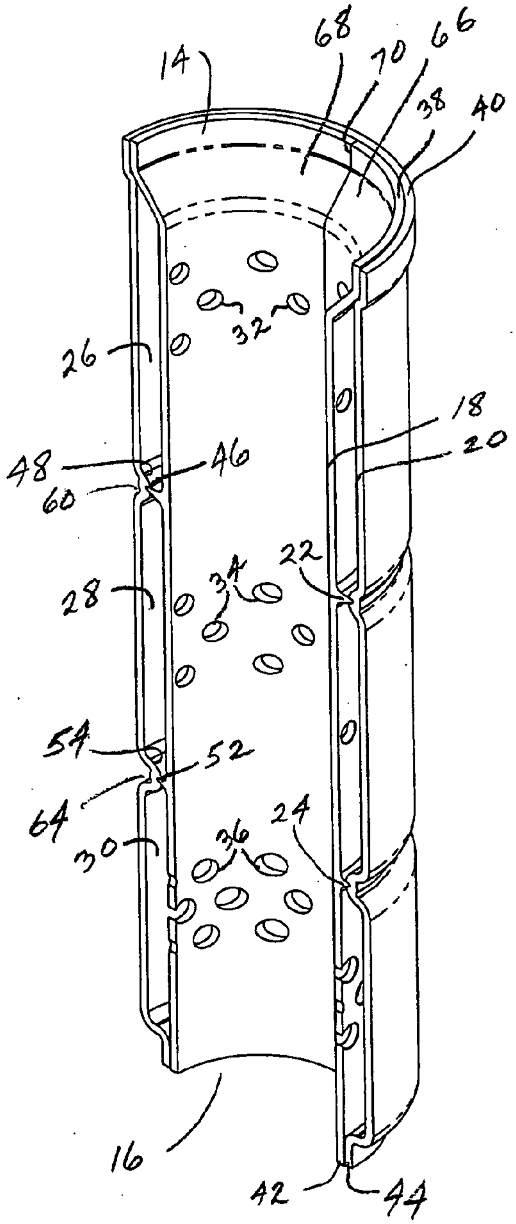
(57) **ABSTRACT**

A resonator includes an inner perforated tube, an outer shell, and a plurality of annular ribs extending radially therebetween and defining resonant chambers. Progressive stepping of ribs and grooves enables axial insertion assembly with minimal cost. The need for welding or secondary bonding operations is eliminated.



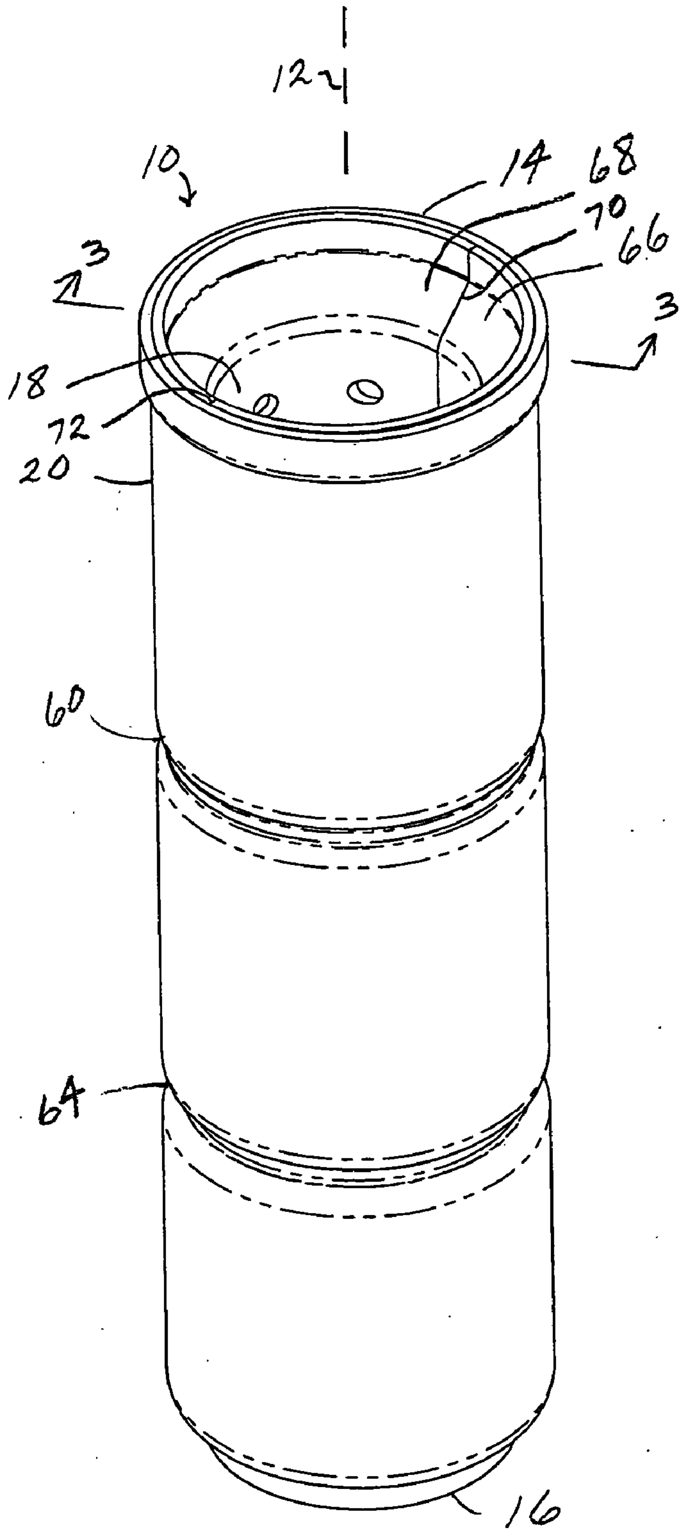


FIG. 1

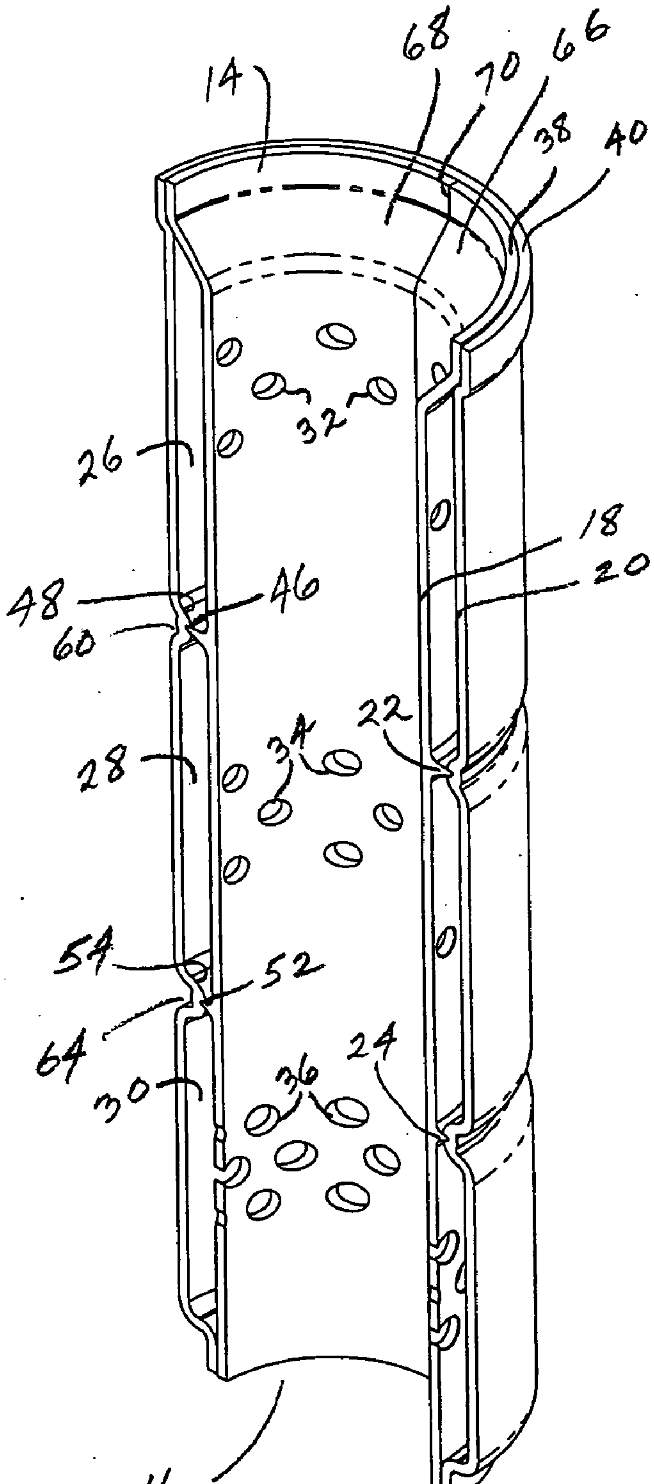

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FIG. 2

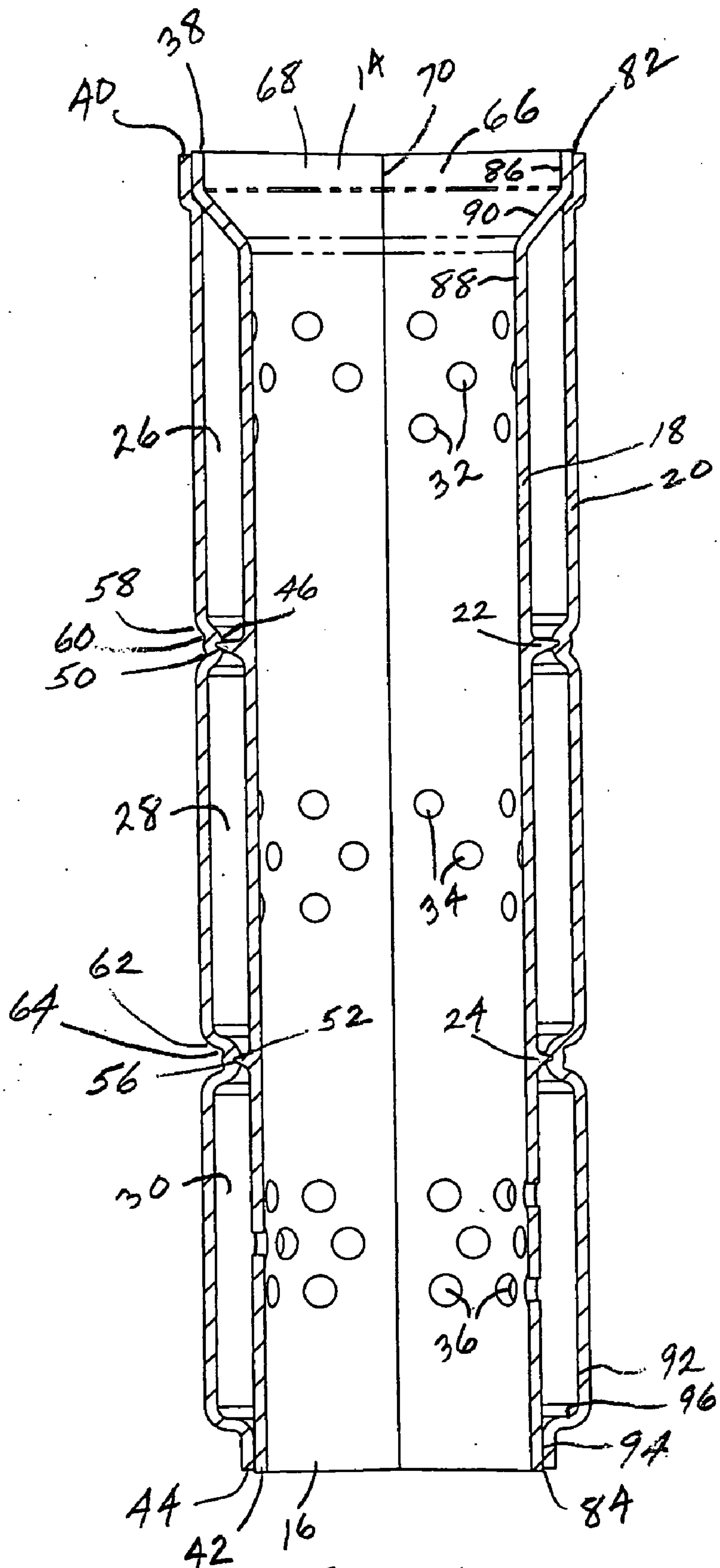
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FIG. 3

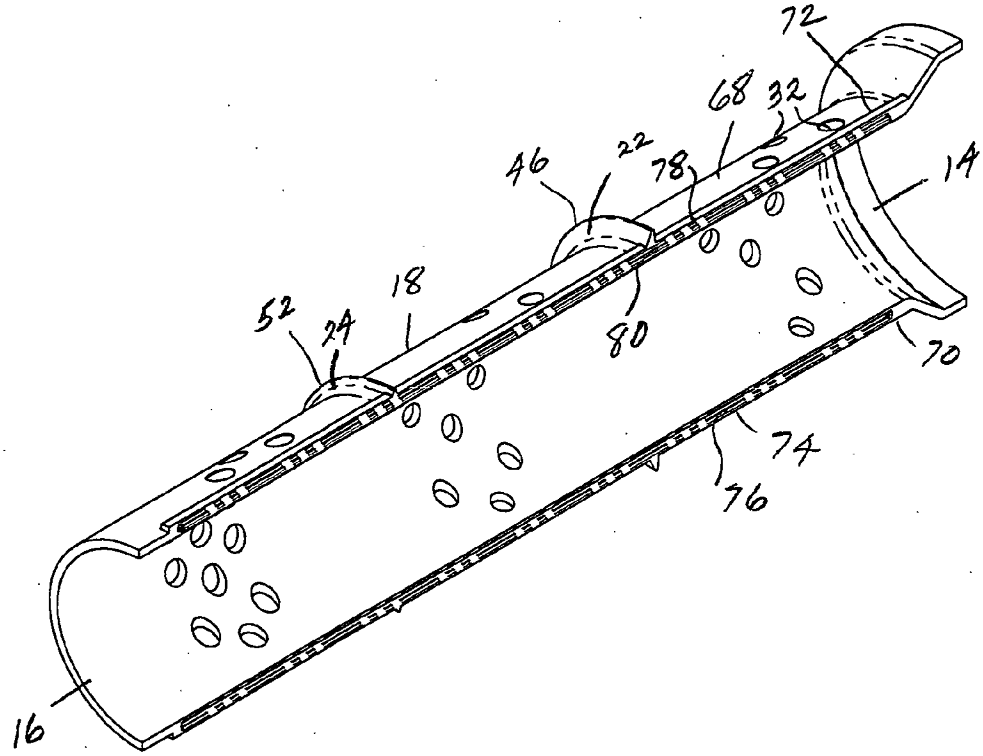

FIG. 4

RESONATOR WITH RETENTION RIBS

BACKGROUND AND SUMMARY

[0001] The invention relates to resonators, including intake resonator silencers for internal combustion engines.

[0002] Intake resonators are known in the art, and are constructed from various materials including metal and/or plastic. Blow molded bottle style resonators are known and fitted under the hood of automobiles, trucks, agricultural and construction vehicles, marine vehicles, and recreational vehicles. Various constructions employ hollow structures made of plastic which are bonded together using vibration or sonic welding or other types of friction welding. Other types of structures have additional elastomer seals, adding expense. Other structures of reduced cost are not gas tight, and therefore lack in performance.

[0003] The present invention provides a simple, cost effective resonator without performance trade-off.

BRIEF DESCRIPTION OF THE DRAWING

[0004] **FIG. 1** is a perspective assembly view of a resonator in accordance with the invention.

[0005] **FIG. 2** is a cut-away view of the assembly of **FIG. 1**.

[0006] **FIG. 3** is a sectional view taken along line **3-3** of **FIG. 1**.

[0007] **FIG. 4** is a perspective view partially cut-away of the inner perforated tube of **FIGS. 1-3**.

DETAILED DESCRIPTION

[0008] **FIG. 1** shows a resonator **10** extending axially along an axis **12** between distally opposite axial ends **14** and **16** providing an inlet and an outlet, respectively, for example for receiving intake combustion air at inlet **14** and delivering the combustion air from outlet **16** to an internal combustion engine (not shown). Resonator **10** has an inner perforated tube **18**, **FIGS. 2-4**, an outer shell **20**, and at least one and preferably two or more annular ribs such as **22**, **24** spaced axially between inlet **14** and outlet **16** and extending radially between inner perforated tube **18** and outer shell **20**. In preferred form, inner tube **18** is an injection molded plastic member, and outer shell **20** is a blow molded or rotationally molded plastic member, and the ribs extend integrally radially outwardly from inner tube **18**. The ribs define a first resonant chamber **26** between inner perforated tube **18** and outer shell **20** axially upstream of rib **22**, a second resonant chamber **28** between inner perforated tube **18** and outer shell **20** axially downstream of rib **22** and axially upstream of rib **24**, and a third resonant chamber **30** between inner perforated tube **18** and outer shell **20** axially downstream of rib **24**. Inner perforated tube **18** has a first set of perforations **32** radially aligned with resonant chamber **26**, a second set of perforations **34** radially aligned with resonant chamber **28**, and a third set of perforations **36** radially aligned with resonant chamber **30**. The resonator attenuates sound waves in gas flow entering the resonator at inlet **14** and exiting the resonator at outlet **16**. The gas flows axially through the hollow interior of perforated tube **18** and communicates with resonant chambers **26**, **28**, **30** through respective sets of perforations **32**, **34**, **36**.

[0009] The set of perforations **32** are the only inlet to and the only exit from resonant chamber **26**, such that gas flow in the hollow interior of inner perforated tube **18** can enter resonant chamber **26** only through the set of perforations **32**, and can exit resonant chamber **26** only through the set of perforations **32**. The second set of perforations **34** are the only inlet to and the only exit from resonant chamber **28**, such that gas flow in inner perforated tube **18** can enter resonant chamber **28** only through the set of perforations **34**, and can exit resonant chamber **28** only through the set of perforations **34**. The third set of perforations **36** are the only inlet to and the only exit from resonant chamber **30**, such that gas flow in inner perforated tube **18** can enter resonant chamber **30** only through the set of perforations **36**, and can exit resonant chamber only through the set of perforations **36**. The upstream inlet ends **38** and **40** of inner tube **18** and outer shell **20**, respectively, engage each other in tight fit flush relation, such that gas flow enters resonator **10** only through the hollow interior of inner tube **18**. The downstream outlet ends **42** and **44** of inner tube **18** and outer shell **20**, respectively, engage each other in tight fit flush relation, such that gas flow exits the resonator at outlet **16** only through the hollow interior of inner perforated tube **18**.

[0010] Rib **22** extends radially outwardly from inner perforated tube **18** and has an outer tip **46**. Outer shell **20** has an inner surface **48** facing radially inwardly toward inner perforated tube **18** and has a sealing engagement surface **50**, **FIG. 3**, engaging outer tip **46** of rib **22** in radially engaged tight fit relation such that inner perforated tube **18** is axially insertable (downwardly in **FIGS. 1-3**) into outer shell **20** and held in radially engaged relation therein, to be further described. Rib **24** extends radially outwardly from inner perforated tube **18** and has an outer tip **52**. Outer shell **20** has an inner surface **54** facing radially inwardly toward inner perforated tube **18** and has a sealing engagement surface **56** engaging outer tip **52** of rib **24** in radially engaged tight fit relation such that inner perforated tube **18** is axially insertable (downwardly in **FIGS. 1-3**) into outer shell **20** and held in radially engaged relation therein, to be further described. Outer tip **46** of rib **22** engages surface **50** in sealing relation, isolating resonant chamber **26** from resonant chamber **28**. Outer tip **52** of rib **24** engages surface **56** in sealing relation, isolating resonant chamber **28** from resonant chamber **30**.

[0011] Resonant chamber **26** is sealed at its upstream end by the flush tight fit engagement of ends **38** and **40** of inner tube **18** and outer shell **20**, respectively, and is sealed at its downstream end by the engagement of rib tip **46** and surface **50**. Resonant chamber **28** is sealed at its upstream end by the engagement of rib tip **46** and surface **50**, and is sealed at its downstream end by the engagement of rib tip **52** and surface **56**. Resonant chamber **30** is sealed at its upstream end by the engagement of rib tip **52** and surface **56**, and is sealed at its downstream end by the flush fit tight engagement of downstream ends **42** and **44** of inner tube **18** and outer shell **20**, respectively.

[0012] Each of sealing engagement surfaces **50** and **56** is a detent engaging the respective outer tip **46** and **50** of the respective rib **22** and **24** in snap-fit relation upon the noted axial insertion. Outer shell **20** has an outer surface **58** with an annular groove **60** recessed radially inwardly toward inner perforated tube **18** and providing the noted sealing engagement surface **50** on inner surface **48**. Outer shell **20** has an outer surface **62** with an annular groove **64** recessed radially inwardly toward inner perforated tube **18** and providing sealing engagement surface **56** on inner surface **54**.

[**0013**] Inner perforated tube **18** is a two-piece member having first and second pieces **66** and **68** abutting each other at first and second axially extending abutment lines **70** and **72** in assembled condition in outer shell **20**. Pieces **66** and **68** are preferably held in assembled condition in outer shell **20** solely by outer shell **20**, without bonding or welding of pieces **66** and **68** to each other. Further preferably, pieces **66** and **68** are identical, which enables the use of a single tool for forming same, to reduce tooling cost. One axially extending edge of each piece, such as edge **74**, **FIG. 4**, along abutment line **70**, is concave as shown at **76**, while the other axially extending edge **78** at abutment line **72** is convex or bulged as shown at **80** to mate in the concave edge of the other piece. Other types of interlocking engagement of pieces **66** and **68** may be used to provide proper alignment of the pieces during axial insertion into outer shell **20**, whereafter the pieces are held in assembled condition by engagement of ribs **22** and **24** with respective detents **50** and **56**.

[**0014**] Inner perforated tube **18** and outer shell **20** have the noted upstream axial ends **38** and **40** mating at an upstream joint **82**, **FIG. 3**, blocking gas flow therepast at inlet **14** such that gas flow at inlet **14** can only flow into the hollow interior of perforated inner tube **18** and not into the space between inner tube **18** and outer shell **20**. Inner perforated tube **18** and outer shell **20** have the noted downstream axial ends **42** and **44** mating at a downstream joint **84** blocking gas flow and sound therepast at outlet **16** such that gas flow at outlet **16** can only flow from the hollow interior of inner perforated tube **18** and not from the space between inner tube **18** and outer shell **20**. The upstream axial end of inner perforated tube **18** has first and second different diameter portions **86** and **88**, **FIG. 3**, and a transition portion **90** therebetween. The diameter of portion **86** is larger than the diameter of portion **88** and mates with outer shell **20**. Transition portion **90** extends radially inwardly from first diameter portion **86** to second diameter portion **88**. The downstream axial end of outer shell **20** has third and fourth different diameter portions **92** and **94** and a transition portion **96** therebetween. The diameter of portion **94** is smaller than the diameter of portion **92** and mates with inner perforated tube **18**. Transition portion **96** extends radially inwardly from third diameter portion **92** to fourth diameter portion **94**.

[**0015**] The number of ribs **22**, **24** equals N, the number of grooves **60**, **64** equals N, and in preferred form, N is greater than or equal to 2, and the number of resonant chambers **26**, **28**, **30** equals N+1, and the number of sets of perforations **32**, **34**, **36** equals N+1. The ribs **22**, **24** have a radial height between inner perforated tube **18** and outer shell **20**, which radial height progressively increases from rib to rib. As seen in **FIGS. 3 and 4**, the radial height of rib **22** is greater than the radial height of rib **24**. The ribs extend radially outwardly from inner perforated tube **18**. Outer shell **20** has the noted plurality of annular grooves **60**, **64** axially spaced from each other and serially axially spaced between inlet **14** and outlet **16** and radially aligned with and engaging respective ribs **22** and **24**. The grooves have a radial depth progressively increasing from groove to groove in inverse relation to the progression of the progressively increasing height of the ribs. As seen in **FIGS. 2 and 3**, the radial depth of groove **64** is greater than the radial depth of groove **60**. The shortest radial height rib **24** engages the deepest radial depth groove **64**. The tallest radial height rib **22** engages the shallowest radial depth groove **60**. This construction facilitates axial insertion of inner perforated tube **18** into outer shell **20**, and enables such axial insertion without a draft on inner tube **18**.

[**0016**] In the present method for assembling a resonator, the inner perforated tube **18** is axially inserted into outer shell **20** (downwardly in **FIGS. 1-3**). First and second pieces **66** and **68** are abutted at axially extending abutment lines **70** and **72** to a pre-assembled condition. The first and second pieces **66** and **68** in the pre-assembled condition are inserted axially into outer shell **20** such that pieces **66** and **68** are held in assembled condition in outer shell **20**, preferably solely by outer shell **20**, without bonding or welding of pieces **66** and **68** to each other. Radial retention force is provided by the snap-fit detent engagement of ribs **22**, **24** and detent sealing engagement surfaces **50**, **56**, respectively. The noted progressive stepping of the ribs and grooves facilitates the noted axial insertion, including without drafting.

[**0017**] It is recognized that various equivalents, alternatives and modifications are possible within the scope of the appended claims.

What is claimed is:

1. A resonator extending axially along an axis between distally opposite axial ends providing an inlet and an outlet, said resonator comprising an inner perforated tube, an outer shell, and at least one annular rib spaced axially between said inlet and said outlet and extending radially between said inner perforated tube and said outer shell and defining a first resonant chamber between said inner perforated tube and said outer shell axially upstream of said rib, and defining a second resonant chamber between said inner perforated tube and said outer shell axially downstream of said rib, said inner perforated tube having a first set of perforations radially aligned with said first resonant chamber, said inner perforated tube having a second set of perforations radially aligned with said second resonant chamber.

2. The resonator according to claim 1 wherein said resonator attenuates sound waves in gas flow entering said resonator at said inlet and exiting said resonator at said outlet, the gas flowing axially through said inner perforated tube and communicating with said first and second resonant chambers through said first and second sets of perforations, respectively.

3. The resonator according to claim 2 wherein said rib isolates said first resonant chamber from said second resonant chamber.

4. The resonator according to claim 2 wherein said rib seals said first resonant chamber from said second resonant chamber.

5. The resonator according to claim 2 wherein:

said first set of perforations are the only inlet to and the only exit from said first resonant chamber, such that gas flow in said inner perforated tube can enter said first resonant chamber only through said first set of perforations, and can exit said first resonant chamber only through said first set of perforations;

said second set of perforations are the only inlet to and the only exit from said second resonant chamber, such that gas flow in said inner perforated tube can enter said second resonant chamber only through said second set of perforations, and can exit said second resonant chamber only through said second set of perforations.

6. The resonator according to claim 5 wherein said gas flow enters said resonator at said inlet only through said inner perforated tube, and said gas flow exits said resonator at said outlet only through said inner perforated tube.

7. The resonator according to claim 2 wherein said rib extends radially outwardly from said inner perforated tube and has an outer tip, and said outer shell has an inner surface facing radially inwardly toward said inner perforated tube and has an engagement surface engaging said outer tip of said rib in radially engaged relation such that said inner perforated tube is axially insertable into said outer shell and held in radially engaged relation therein.

8. The resonator according to claim 7 wherein said outer tip of said rib engages said engagement surface in sealing relation isolating said first resonant chamber from said second resonant chamber.

9. The resonator according to claim 7 wherein said engagement surface comprises a detent engaging said outer tip of said rib in snap-fit relation.

10. The resonator according to claim 7 wherein said outer shell has an outer surface with an annular groove recessed radially inwardly toward said inner perforated tube and providing said engagement surface.

11. The resonator according to claim 2 wherein said inner perforated tube and said outer shell have upstream axial ends mating at an upstream joint blocking gas flow therepast at said inlet such that gas flow at said inlet can only flow into said perforated inner tube and not into the space between said inner perforated tube and said outer shell, and wherein said inner perforated tube and said outer shell have downstream axial ends mating at a downstream joint blocking gas flow therepast at said outlet such that gas flow at said outlet can only flow from said perforated inner tube and not from the space between said inner perforated tube and said outer shell.

12. The resonator according to claim 11 wherein:

one of said upstream axial ends of said inner perforated tube and said outer shell has first and second different diameter portions and a first transition portion therebetween, said first diameter portion being larger than said second diameter portion and mating with the other of said upstream axial ends of said inner perforated tube and said outer shell, said first transition portion extending radially inwardly from said first diameter portion to said second diameter portion;

one of said downstream axial ends of said inner perforated tube and said outer shell has third and fourth different diameter portions and a second transition portion therebetween, said third diameter portion being larger than said fourth diameter portion and mating with the other of said downstream axial ends of said inner perforated tube and said outer shell, said second transition portion extending radially inwardly from said third diameter portion to said fourth diameter portion.

13. The resonator according to claim 11 wherein:

said upstream axial end of said inner perforated tube has first and second different diameter portions and a first transition portion therebetween, said first diameter portion being larger than said second diameter portion and mating with said outer shell, said first transition portion extending radially inwardly from said first diameter portion to said second diameter portion;

said downstream axial end of said outer shell has third and fourth different diameter portions and a second transition portion therebetween, said fourth diameter portion being smaller than said third diameter portion and mating with said inner perforated tube, said second transition portion extending radially inwardly from said third diameter portion to said fourth diameter portion.

14. The resonator according to claim 1 wherein said inner perforated tube is a two-piece member having first and second pieces abutting each other at first and second axially extending abutment lines in an assembled condition in said outer shell, and wherein said first and second pieces are held in said assembled condition in said outer shell solely by said outer shell, without bonding or welding of said first and second pieces to each other.

15. The resonator according to claim 1 wherein said inner perforated tube is a two-piece member having first and second pieces abutting each other at first and second axially extending abutment lines in an assembled condition in said outer shell, said first and second pieces being identical and enabling the use of a single tool for forming same, to reduce tooling cost.

16. A resonator extending axially along an axis between distally opposite axial ends providing an inlet and an outlet, said resonator comprising an inner perforated tube, an outer shell, and a plurality of annular ribs axially spaced from each other and serially axially spaced between said inlet and said outlet and extending radially between said inner perforated tube and said outer shell and defining a plurality of resonant chambers between said inner perforated tube and said outer shell, said inner perforated tube having a plurality of sets of perforations radially aligned with respective said resonant chambers.

17. The resonator according to claim 16 wherein the number of said ribs equals N, where $N \geqq 2$, the number of said resonant chambers equals N+1, and the number of said sets of perforations equals N+1.

18. The resonator according to claim 16 wherein said ribs have a radial height between said inner perforated tube and said outer shell, and wherein said radial height progressively increases from rib to rib.

19. The resonator according to claim 18 wherein said ribs extend radially outwardly from said inner perforated tube, said outer shell has a plurality of annular grooves axially spaced from each other and serially axially spaced between said inlet and said outlet and radially aligned with and engaging respective said ribs, and wherein said grooves have a radial depth progressively increasing from groove to groove in inverse relation to the progression of said progressively increasing height of said ribs.

20. The resonator according to claim 19 wherein the shortest radial height rib engages the deepest radial depth groove, and the tallest radial height rib engages the shallowest radial depth groove.

21. The resonator according to claim 20 wherein said inner perforated tube is insertable axially into said outer shell, and wherein said progressively increasing radial depth of said grooves in inverse relation to the progression of the progressively increasing height of said ribs facilitates said axial insertion.

22. The resonator according to claim 19 wherein the number of said ribs equals N, where $N \geqq 2$, the number of said grooves equals N, the number of said resonant chambers equals N+1, and the number of said sets of perforations equals N+1.

23. A method for assembling a resonator extending axially along an axis between distally opposite axial ends, namely an inlet and an outlet, comprising providing an inner perforated tube, providing an outer shell, providing at least one annular rib on one of said inner perforated tube and said outer shell, and axially inserting said inner perforated tube into said outer shell.

24. The method according to claim 23 comprising axially inserting said inner perforated tube into said outer shell such that said rib is spaced axially between said inlet and said outlet and extends radially between said inner perforated tube and said outer shell and defines a first resonant chamber between said inner perforated tube and said outer shell axially upstream of said rib, and defines a second resonant chamber between said inner perforated tube and said outer shell axially downstream of said rib, providing said inner perforated tube with a first set of perforations radially aligned with said first resonant chamber, providing said inner perforated tube with a second set of perforations radially aligned with said second resonant chamber.

25. The method according to claim 24 comprising providing said rib extending radially outwardly from said inner perforated tube and having an outer tip, providing said outer shell with an inner surface facing radially inwardly toward said inner perforated tube and having an engagement surface, axially inserting said inner perforated tube into said outer shell such that said outer tip of said rib engages said engagement surface in radially engaged relation such that said inner perforated tube and said outer shell are held in radially engaged relation.

26. The method according to claim 25 comprising engaging said outer tip of said rib and said engagement surface in sealing relation isolating said first resonant chamber from said second resonant chamber.

27. The method according to claim 25 comprising providing said engagement surface as a detent, and inserting said inner perforated tube into said outer shell such that said outer tip of said rib engages said detent in snap-fit relation.

28. The method according to claim 25 comprising providing said outer shell with an outer surface having an annular groove recessed radially inwardly toward said inner perforated tube and having an inner surface providing said engagement surface, and comprising inserting said inner perforated tube axially into said outer shell such that said outer tip of said rib engages said engagement surface.

29. The method according to claim 23 comprising providing said inner perforated tube as a two-piece member having first and second pieces, abutting said first and second pieces at first and second axially extending abutment lines to a pre-assembled condition, inserting said first and second pieces in said pre-assembled condition axially into said outer shell such that said first and second pieces are held in assembled condition in said outer shell solely by said outer shell, without bonding or welding of said first and second pieces to each other.

30. The method according to claim 23 comprising providing said inner perforated tube as a two-piece member having identical first and second pieces, abutting said first and second pieces to each other at first and second axially extending abutment lines in a pre-assembled condition, axially inserting said first and second pieces in said pre-assembled condition into said outer shell.

31. The method according to claim 30 comprising forming said first and second identical pieces by the same tool, to reduce tooling cost.

32. A method for assembling a resonator extending axially along an axis between distally opposite axial ends, namely an inlet and an outlet, comprising providing an inner perforated tube, providing an outer shell, providing a plurality of annular ribs axially spaced from each other and serially axially spaced between said inlet and said outlet for extending radially between said inner perforated tube and said outer shell and defining a plurality of resonant chambers between said inner perforated tube and said outer shell, providing said inner perforated tube with a plurality of sets of perforations to be radially aligned with respective said resonant chambers, and axially inserting said inner perforated tube into said outer shell.

33. The method according to claim 32 comprising providing N said ribs, where $N \geqq 2$, providing N+1 said resonant chambers, and providing N+1 said sets of perforations.

34. The method according to claim 32 comprising providing said ribs with a radial height extending between said inner perforated tube and said outer shell, and progressively increasing said radial height from rib to rib.

35. The method according to claim 32 comprising providing said ribs extending radially outwardly from said inner perforated tube, providing said outer shell with a plurality of annular grooves axially spaced from each other and serially axially spaced between said inlet and said outlet and radially aligned with and engaging respective said ribs, providing said grooves with a radial depth progressively increasing from groove to groove in inverse relation to the progression of said progressively increasing height of said ribs.

36. The method according to claim 35 comprising, upon axial insertion of said inner perforated tube into said outer shell:

engaging the shortest radial height rib with the deepest radial depth groove; and

engaging the tallest radial height rib with the shallowest radial depth groove.

37. The method according to claim 36 comprising providing said inner perforated tube without a draft, and inserting said inner perforated tube axially into said outer shell without a draft.

38. The method according to claim 35 comprising providing N said ribs, where $N \geqq 2$, providing N said grooves, providing N+1 said resonant chambers, and providing N+1 said sets of perforations.

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