International Journal of Engineering & Technology, 7 (4.10) (2018) 869-872

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

On WS Closed and WS Open Maps in Topological Spaces

Veeresha A Sajjanar[1*] , Basavaraj M. Ittanagi [2]

[1]*Department of Mathematics, Sri Krishna Institute of Technology,, Bangalore, Karnataka State, India*
[2]*Department of Mathematics, Siddaganga Institute of Technology, Tumakuru, Karnataka State, India*
**Corresponding author E-mail: veereshas@rediffmail.com*

Abstract

New type of closed and open maps called ws-closed and ws-open maps in topological spaces are introduced and studied. During this process some of their properties have been investigated. Also we introduce ws*-closed and ws*-open maps in topological spaces and discuss some properties.

***Keywords**: : ws–Closed maps, ws*-Closed maps and ws–open maps, ws*-open maps.*

1. Introduction

In 1982, the concept of generalized closed maps is introduced and studied by S. R, Malghan [4], After regular , rw, αrw-closed maps are elaborated by Long [3] Benchalli et. all [2] and R S Wali et. all [6] respectively. Intention of paper is to illustrate and study ws-closed and ws-open maps, ws*-closed and ws*-open maps in topological spaces, Also some of their properties have been investigated.

2. Preliminaries

Here P or (P ,τ) and Q or (Q,σ) indicate topological spaces for which, separation axioms are not assumed. For, a subset D of a topological space P, cl(A), int(A), P -D or D^c represent closure of D, interior of D and complement of D in P respectively. CLD refers short form of Closed and $(CLD)^1$ refers short form of Open

Definition 2.1: A map h is said, to be

i. ws– Continuous [1] if $h^{-1}(V)$ is ws–CLD in P, ∀ CLD subset V of Q.
ii. Strongly ws–continuous [1], if $h^{-1}(V)$ is CLD set in P ∀ ws–CLD set V in Q.

Definition 2.2:A map h is said to be

i. ws– irresolute [1] if $h^{-1}(V)$ is ws–CLD in P ∀ ws-CLD subset V of Q.

Results 2.3: [1]

i. A subset *D* of a space (P,τ) is called ws-CLD set if scl(D) ⊆ U , whenever D ⊆ U and U is w-open in (P, τ).
ii. Every CLD (respectively, semi-CLD, α, g# *gα, gξ*, $\ddot{g}$, regular, rb, g#s- CLD) set is ws-CLD set in P.
iii. Every ws-CLD set is gspr-CLD (respectively, gsp, rgb-CLD) set in P.

Results 2.4: [1] Aysubset D of astopologicalgspace P, and

i. If D is regular open and gspr-CLD set then D is ws-CLD set in P.
ii. If D is regular open and rgb-CLD set then D is ws-CLD set in P.
iii. If D is semiopen and swg*-CLD then D is ws-CLD set,in P.
iv. If D is semiopen and swg-CLD then D is ws-CLD set, in P.
v. If D is semiopen and sg-CLD then D is ws-CLD set, in P.
vi. If D is semiopen and sgb-CLD then D is ws-CLD set, in P.
vii. If D is semiopen and αgs-CLD then D is ws-CLD set,in P.
viii. If D is β-open and βwg*-CLD then D is ws-CLD set, in P.
ix. If D is both open and g-CLD then D is ws-CLD set, in P.
xi. If D is regular semiopen and rw-CLD then D is ws-CLD set, in P.
xii. If D is regular semiopen and R*-CLD then D is ws-CLD set, in P.
xiii. If D is regular semiopen and gprw-CLD then D is ws-CLD set, in P.
xiv. If D is regular semiopen and rgw-CLD then D is ws-CLD set in P.

Definition, **2.5:** ,Topological space P is called

i. $T_{½}$,space [4] if every semi-CLD set is CLD.
ii. T_{ws} space [1] if every ws-CLD set is CLD.

Definition, **2.6:** A map h is, said to, be

i. w-open map [5] if f (U) is w-open in Q for every open set U of P,

3. ws–CLD Maps and ws–$(CLD)^1$ Maps

Definition 3.1: A map h is, said to, be,weakly, semi-CLD (briefly ws-CLD) map,, if the, image of ∀ CLD set in (P, τ) is ws–CLD in (Q, σ).

Example 3.2,: Let P = Q = { v_a, v_b, v_c}, τ ={ P, ϕ, {v_a}, {v_b}, { v_a, v_b }} be a topology on P. σ ={ Q, ϕ, { v_a }, { v_b, v_c }} be a topology on Q and wsC(Q) ={ Q, ϕ, { v_b },{v_c},{ v_a, v_c },{ v_b, v_c }}. Let h defined by identity map, then h is ws–CLD map.

Theorem, 3.3:, Every CLD map is ws–CLD map, but**,** reverse is not true..

Proof,: Let h be CLD map and**,** V,be any CLD set in P. Then h (V) is CLD set in Q, since every CLD set is ws–CLD set. Hence h (V) is ws-CLD set in Q. Therefore h is ws -CLD.

Example 3.4: Let P = Q = { v_a, v_b, v_c} τ ={ P, ϕ, {v_b}, { v_c}, { v_a, v_c}, { v_b, v_c}} be a topology on P. σ ={ Q, ϕ, { v_a }, { v_b }, { v_a, v_b }} be a topology on Q and wsC(Q) = { Q, ϕ,{ v_a }, { v_b },{ v_c },{ v_a, v_c },{ v_b, v_c }}. Let h defined by identity map, then h is ws–CLD map but, not CLD as image, of CLD set {b}, in P is {b}, which is not CLD set in Q.

Theorem 3.5: If h is a CLD map then the following holds.

i. Every, semi-CLD is ws-CLD but**,** reverse is not true.
ii. ∀ α -CLD is ws-CLD but**,** reverse is not true.
iii. ∀ $g^{\#}$-CLD is ws-CLD but**,** reverse is not true.
iv. ∀ *gα-CLD is ws-CLD but**,** reverse is not true.
v. ∀ $g\xi^*$-CLD is ws-CLD but**,** reverse is not true.
vi. ∀ αgp-CLD is ws-CLD but**,** reverse is not true.
vii. ∀ $\ddot{g}$ -CLD is ws-CLD but**,** reverse is not true.
viii. ∀ regular-CLD is ws-CLD but**,** reverse is not true.
ix. ∀ rb-CLD is ws-CLD but**,** reverse is not true.

Proof:, The proof**,** based on fact that ∀ semi CLD set (respectively, α, g#-, *gα, $g\xi^*$, $\ddot{g}$, regular, rb-CLD set) is ws–CLD set.
The reverse, of above Theorem 3.5 is not true as elaborated in Example 3.6.

Example 3.6: Let P = Q = { v_a, v_b, v_c} τ ={P, ϕ, { v_b },{ v_c },{ v_a, v_c }, { v_b, v_c }} be a topology on P and σ ={ Q, ϕ, { v_a }, { v_b}, { v_a, v_b}} be a topology on Q and wsC(Q)={ Q, ϕ,{ v_a }, { v_b },{ v_c },{ v_a, v_c },{ v_b, v_c }}. Let h defined by identity map, then h is ws–CLD map but not CLD as ,image, of CLD set { v_b } in P is { v_b }, which is not semi-CLD set (respectively α, g#-, *gα, $g\xi^*$, $\ddot{g}$, regular, rb-CLD set) in Q.

Theoremg3.7: Every $g^{\#}$s -CLD map is ws–CLD map, but reverse is not true.
Proof: The, proof based on the fact that every $g^{\#}$s -CLD set is ws–CLD set.

Example 3.8: Let P ,= Q, = {v_a, v_b, v_c, v_d}. Let τ= {ϕ, P, { v_a, v_b }, { v_c, v_d}}be a topology on P and σ ={ϕ, Q, { v_a }, { v_b }, { v_a, v_b }, { v_a, v_b, v_c }} be a topology on Q and wsC(Q)={Q,ϕ { v_a },{ v_b},{ v_c},{d},{ v_a, v_c }, { v_a, v_d},{ v_b, v_c},{ v_b, v_d},{ v_c d},{ v_a, v_b, v_d }, { v_a, v_c, }, { v_b, v_c, v_d }}, $g^{\#}$sC(Q)={ Q, ϕ, { v_b },{ v_c },{ v_d },{ v_b, v_c },{ v_b, v_d }, { v_c, v_d },{ v_b, v_c, v_d }}. Let h: (P, τ)→ (Q, σ)) be a function defined by h(v_a)= v_a, h(v_b)= v_b, h(v_c)= v_c, h(d)=d, is ws–CLD map but not CLD as image, of CLD set { v_a, v_b} in P is { v_a, v_d }, is not $g^{\#}$s -CLD set in Q.

Theoreme 3.9: If h is a CLD map then the following holds.

i. Every ws–CLD map is gspr-CLD map but reverse is not true.
ii. Every ws–CLD map is gsp-CLD map but reverse is not true.
iii. Every ws–CLD map is rgb-CLD map but reverse is not true.

Proofe: The proof based on the fact that every ws–CLD set is gspr CLD set (respectively, rgb, gsp-CLD set).

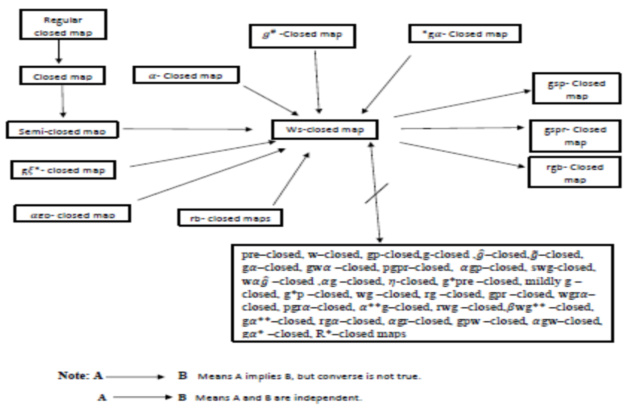
Example 3.10: Let P = Q = {v_a, v_b, v_c, v_d}. Let τ= {ϕ, P, { v_a }, { v_b}, { v_a, v_b },{ v_a, v_b, v_c}}be a topology on P and σ={ϕ, Q, { v_a, v_b }, { v_c, v_d }} be a topology on Q and wsC(Q)= { Q, ϕ, {v_a, v_b}, { v_c, v_d }}, gsprC(Q)=gspC(Q)=rgbC(Q)={P(Q)}. Let h defined by f (v_a) = v_a, f (v_b) = v_b, f(v_c) = v_c, f(v_d)= v_d, then h is gspr-CLD map (respectively, rgb, gsp-CLD)but not ws-CLD as image of CLD set { v_d } in P is { v_d },is, not ws -CLD setiin Q.

Remark 3.11: The following Examples 3.12 and 3.13, shows that ws-CLD maps are independent of pre–CLD, w, gp, g, $\hat{g}$, $\tilde{g}$, gα, gwα, pgpr, αgp, swg, wα $\hat{g}$,αg , η, g*pre, mildly g, g*p, wg, rg, gpr, wgrα, pgrα, α**g, rwg, βwg**, gα**, rgα, αgr, gpw, αgw, gα*, R*–CLD.

Example 3.12: Let P = Q = { v_{ai}, v_{bi}, v_{ci}, v_{di} }. Let τ= {ϕ, P, { v_a}, { v_a, v_b },{ v_a, v_b, v_c}}be a topology on P and σ={ϕ, Q, { v_a, v_b }, { v_c, v_d}} be a topology on Q and wsC(Q)= { Q, ϕ, { v_a, v_b }, { v_c, v_d }}. Let h defined by, h(v_a)= v_a, h(v_b) = v_b, h(v_c) = v_c, h(v_d)= v_d, ,then h is of pre–CLD, w, gp, g, $\hat{g}$, $\tilde{g}$, gα, gwα, pgpr, αgp, swg, wα $\hat{g}$,αg , η, g*pre, mildly g, g*p, wg, rg, gpr, wgrα, pgrα, α**g, rwg, βwg**, gα**, rgα, αgr, gpw, αgw, gα*, R*–CLD maps. But h is not ws–CLD map, as CLD set { v_d} in P is { v_d}, is not ws–CLD set in Q.

Example 3.13: Let P = Q = { v_{ai}, v_{bi}, v_{ci}, v_{di} }. Let τ= {ϕ, P, { v_a, v_b }, { v_c, v_d }}be a topology on P and σ={ϕ, Q, { v_a }, { v_b}, { v_a, v_b}, { v_a, v_b, v_c } } be a topology on Q and wsC(Q)={ϕ, Q,{ v_a },{ v_b },{ v_c },{ v_d},{ v_a, v_c }, { v_a, v_d},{ v_b, v_c },{ v_b, v_d }, { v_c, v_d }, { v_a, v_b, v_d,}, { v_a, v_c, v_d }, { v_b, v_c, v_d }}. Let h: (P, τ) → (Q, σ) defined by, f(v_a) = v_a, f(v_b) = v_a, f(v_c) = v_c, f(v_d)= v_d, then h is ws–CLD, but not a pre–CLD(respectively, w, gp, g, $\hat{g}$, $\tilde{g}$, gα, gwα, pgpr, αgp, swg, wα $\hat{g}$,αg , η, g*pre, mildly g, g*p, wg, rg, gpr, wgrα, pgrα, α**g, rwg, βwg**, gα**, rgα, αgr, gpw, αgw, gα*, R*–CLD) maps as CLD set { v_a, v_b} in P is { v_a}, is not pre–CLD(respectively, w, gp, g, $\hat{g}$, $\tilde{g}$, gα, gwα, pgpr, αgp, swg, wα $\hat{g}$,αg , η, g*pre, mildly g, g*p, wg, rg, gpr, wgrα, pgrα, α**g, rwg, βwg**, gα**, rgα, αgr, s gpw, αgw, gα*, R*–CLD) set in Q.

Remark 3.14: By the known facts, the relation between ws-CLD map and some existing CLD maps in topological space is shown in the following figure.



Theorem 3.15: If a map h is contra regular CLD and gspr-CLD map then h is ws-CLD map in P.

Proof: Let U be any CLD set in P, Then h(U) is open and gspr –CLD set in Q. By results 2.4, h(U) is ws–CLD in Q. Therefore h is ws–CLD map.

Theoreme3.16: A map h is contra CLD and rgb-CLD map then h is ws-CLD map in P.

Proof: Let U be any CLD set in P. Then h(U) is open and rgb –CLD set in Q. By results 2.4 h(U) is ws–CLD in Q. Therefore h is ws–CLD map.

Theorem 3.17: A map h is contra CLD and αg–CLD map then h is ws–CLD map.

Proof: Let U be any CLD set in P. Then h (U) is open and αg–CLD set in Q. By results 2.4, h(U) is ws–CLD in Q. Therefore h is ws–CLD map.

Theorem 3.18: If a map h is contra CLD and rgb-CLD map then h is ws-CLD map in P.

Proof: Let U be any CLD set in P. Then h(U) is open and rgb –CLD set in Q. By results 2.4, h(U) is ws–CLD in Q. Therefore h is ws–CLD map.

Theorem 3.19: If a map h is contra semi CLD and swg*-CLD map then h is ws-CLD map in P.

Proof: Let U be any CLD set in P Then h(U) is semi open and swg*–CLD set in Q. By results 2.4, h(U) is ws–CLD in Q . Therefore h is ws–CLD map.

Theorem 3.20: If a map h is contra semi CLD and swg-CLD map then h is ws-CLD map in P.

Proof: Let U be any CLD set in P. Then h(U) is semi open and swg –CLD set in Q. By results 2.4, h(U) is ws–CLD in Q. Therefore h is ws–CLD map.

Theorem 3.21: If a map h is contra is semi CLD and sg-CLD map then h is ws-CLD map in P.

Proofg: Let U be any CLD set in P. Then h(U) is semi open and sg –CLD set in Q. By results 2.4, h(U) is ws–CLD in Q. Therefore h is ws–CLD map.

Theorem 3.22: If a map h is contra is semi CLD and sgb-CLD map then h is ws-CLD map in P

Proofg: Let U be any CLD set in P. Then h(U) is semi open and sgb –CLD set in Q. By results 2.4, h(U) is ws–CLD in Q. Therefore h is ws–CLD map.

Theorem 3.23: A map h is contra is semi CLD and αgs-CLD map then h is ws-CLD map in P.

Proofg: Let U be any CLD set in P. Then h(U) is semi open and αgs –CLD set in Q. By results 2.4, h(U) is ws–CLD in Q .Therefore h is ws–CLD map.

Theorem 3.24: If h is contra is β-CLD and βwg*-CLD map then h is ws-CLD map in P.

Proofg: Let U be any CLD set in P. Then h(U) is β- open and βwg*-–CLD set in Q. By results 2.4, h(U) is ws–CLD in Q. Therefore h is ws–CLD map.

Theorem 3.25: If h is contra is both CLD and g-CLD map then f is ws-CLD map in P**.**

Proofg: Let V be any CLD set in P. Then f(U) is open and g–CLD set in Q. By results 2.4, h(U) is ws–CLD in Q. Therefore h is ws–CLD map.

Theorem 3.26: If **h** is contra is regular semi CLD and rw-CLD map then h is ws-CLD map in P**.**

Proofg: Let U be any CLD set in P. Then h(U) is semi open and rw –CLD set in Q. By results 2.4, h(U) is ws–CLD in Q. Therefore *f* is ws–CLD map.

Theorem 3.27: If f is contra is regular semi CLD and R*-CLD map then h is ws-CLD map in P.

Proofg: Let U be any CLD set in P. Then h(U) is semi open and R*-CLD set in Q. By results 2.4, h(U) is ws–CLD in Q. Therefore h is ws–CLD map.

Remarkt 3.28: Thetcompositioneofbtwo ws–CLD maps not reqired to be ws–CLD mapeintgeneralrandgthisdis showntbydthe efollowing example 3.29.

Example 3.29: Let P = Q = R = { v_a, v_b, v_c }, τ={ P, ϕ, { v_a }, { v_b, v_c }} be a topology on P, σ = { Q, ϕ, { v_a },{ v_b },{ v_a, v_b }} be a topology on Q and η = {R, ϕ, { v_a }, { v_b }, { v_a, v_b }, { v_a, v_c }} be a topology on R. Define h: P → Q, defined by $f(v_a)= v_a$, $f(v_b)= v_b$, $f(v_c)= v_c$ and g: Q→ R are the identity maps. Then h and g are ws–CLD maps, but theirEcomposition g ∘h : P→ R is not ws–CLD map, because E = { v_a } is CLD in P but g ∘h(E) =g ∘h({v_a}) = g(h({v_a})) = g({v_a}) = { v_a} is not ws–CLD in R.

Theorem 3.30: If h is CLD map , g: Q→ R is ws–CLD map, thenrthetcomposition g ∘h: P → R is ws–CLD .
Proofg: Let E be any CLD set in P. Since h is CLD , h(E) is CLD set in Q. g is ws–CLD , g (h(E)) is ws–CLD set in R. That is g ∘h(E) = g (h(E)) is ws–CLD and hence g ∘h ws–CLD.

Theorem 3.31: If h: P → Q and g: Q→ R is ws–CLD maps and Q be Tws-space then g∘h: P→ R is ws–CLD map.

Proofg: Let E be a CLD set of P. h is ws–CLD, h(E) is ws–CLD in (Q, σ). Then by hypothesis, h(E) is CLD. Since g is ws–CLD, g (h(E)) is ws–CLD in R and g(h(E)) = g ∘h(E). Hence g ∘h is ws–CLD.

Theoreme 3.32: If h : P →Q is g-CLD, g: Q → R be ws–CLD and Q is $T_{1/2}$-space then their composition g ∘ h: P → R is ws–CLD map.

Proof: Let E be a CLD set of P. Since h is g-CLD, h(E) is g-CLD in Q. Since Q is T1/2-space, h(E) is CLD in Q. Since g is ws–CLD, g (h(E)) is ws–CLD in R and g(h (E)) = g ∘ h(E). Therefore g ∘ h is ws–CLD map.

Definitione3.33: A map h is ws–open map if the image h(E) is ws–open in Q for each open set E in P. From the definitions we have the following results.

Theorem 3.34:

i. ∀ $(CLD)^1$ map is ws–$(CLD)^1$ but reverse is not true.
ii. ∀ semi-$(CLD)^1$ map is ws–$(CLD)^1$ but reverse is not true.
iii. ∀ α -$(CLD)^1$ map is ws–$(CLD)^1$ but reverse is not true.
iv. ∀ g#-$(CLD)^1$ map is ws–$(CLD)^1$ but reverse is not true

v. ∀ *g α -(CLD)[1] map is ws–(CLD)[1] but reverse is not true.
vi. ∀ g ξ^* -(CLD)[1] map is ws–(CLD)[1] but reverse is not true.
vii. ∀ αgp-(CLD)[1] map is ws–(CLD)[1] but reverse is not true.
viii. ∀ $\ddot{g}$ -(CLD)[1] map is ws–(CLD)[1] but reverse is not true.
ix. ∀ rb-regular (CLD)[1] map is ws–(CLD)[1] but reverse is not true.
x. ∀g#s (CLD)[1] map is ws–(CLD)[1] but reverse is not true.
xi. ∀ ws–(CLD)[1] map is gspr-(CLD)[1] but reverse is not true
xii. ∀ ws–(CLD)[1] map is gsp-(CLD)[1] but reverse is not true.
xiii. ∀ ws–(CLD)[1] map is rgb-(CLD)[1] but reverse is not true.

Theorem 3.35: Bijection map h the Conditions below aretequivalent:
i) h^{-1} is ws–tcontinuous.
ii) h is ws–(CLD)[1] tmap and
iii) h is ws–CLD tmap.
Proof:
(i) ⇒ (ii) Let M is (CLD)[1]gset, of (P, τ). By consideration, $(h^{-1})^{-1}(M)$ = h (M) is ws–open in (Q, σ) and so h is ws–(CLD)[1].
(ii) ⇒ (iii) Let N is a CLD set of (P, τ). Then N^c isdopen gset in (P, τ). By assumption, $h(N^c)$ is ws–open in (Q, σ). That is $h(N^c) = h(N)^c$ is ws–opendin (Q, σ) and therefore h(N) is ws– CLD in Q. Hence h is ws–CLD.
(iii) ⇒ (i) Let N is a CLD set of P. By cosideration, h(N) is ws–CLD in Q. But h(N) = $(h^{-1})^{-1}$ (N) and therefore h^{-1} is continuous.

TheoremE3.36: If h is ws–open, then h(int (B)) ⊆ ws–int (h(B)) forGeverygsubset A of P.

Proofg: Let h be anTopendmap and B be ranytsubset of P. Then int (B) isdopen in P andeso h(int (B)) is ws–open in (Q, σ). We have h(int (B)) ⊆h(B). Therefore h(int (B)) ⊆ ws–int (h(B)).

Definitionr3.37: If h is said to be ws*- CLD map if the timage h (B) is ws–CLD in Q for every ws–CLD set B in P.

Thereme3.38: Every ws*-CLD map is ws–CLD map but reverse is not true.
Proofg: The proof follows from the definitions and fact that every CLD set is ws–CLD.

Examplev 3.39: Let P = Q = { v_a, v_b, v_c }, τ = { P, ϕ, { v_a }, { v_b }, { v_a, v_b }} be a topology on P and σ ={ Q, ϕ, { v_a }, { v_b },{ v_a, v_b },{ v_a, v_c }} be a topology on Q and h be theridentityemap. Then h is ws–CLD map but not ws*-CLD map. Since {a} is ws–CLD set in P. but its image under h is {v_a}, which is not ws–CLD in Q.

Theoremf3.40: If h: P → Q and g: Q → R are ws*-CLD maps, then their composition g ∘ f: P → R is also ws∗-CLD.

Proofg: Let E be a ws–CLD set in P. Since h is ws*– CLD map, h(E) is ws–CLD set in Q. Since ws∗– CLD map, g (h(E)) is ws–CLD set in R. Therefore g ∘h is ws*–CLD map. Analogous to ws*-CLD map, we define another new class of maps called ws*–open maps which are stronger than ws–(CLD)[1] maps.

Definitiond3.41: A map h: P → Q is said to be ws∗– open map if the image h(E) is ws–(CLD)[1] set in Q for every ws–open set E in P.

Theoreme3.42: Every ws∗–(CLD)[1] map is ws–open map but reverse is not true.

Proofg: Proof is similar to the Theorem 3.40, fact that every open set is a ws– (CLD)[1] set.

Examplet 3.43: Let P = Q = {v, v_b, v_c }, τ = { P, ϕ, {v_a}, {v_b}, {v_a, v_b }} and σ ={Q, ϕ, { v_a }, { v_b }, { v_a, v_b },{ v_a, v_c }} and h be the identity map. Then h is ws –open map but not ws*-open map. Since { v_b, v_c } is ws–open set in P, but its image under h is {v_b, v_c }, is not ws–(CLD)[1] in Q.

Theoreme 3.44: If h: P→ Q and g: Q → R are ws∗-open maps, their composition g ∘h: P → R is also ws∗-(CLD)[1].

Proofg: Proof is similar to the Theorem 3.35.

Theoreme 3.45: Bijection map h the condtions below are equivalent:
1. h^{-1} is ws irresolute.
2. h is ws∗–(CLD)[1] map
3. h is ws∗–CLD map.

Proof: Proof is similar to that of Theorem 3.40.

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